

Permian Brachiopods from the Khao Hin Kling Area near Phetchabun, North-central Thailand

Juichi YANAGIDA¹ and Nikorn NAKORNSRI²

¹Izumi 3-60, Kasuga-shi, Fukuoka-ken 816-0853, Japan

²1004/3 Soi Udomsuk 56, Sukumvit 103 Road,

Bang Na, Bangkok 10260, Thailand

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Abstract This paper deals with Permian brachiopods collected from 7 localities in the Tak Fa Formation of the Rat Buri Group, developed in the Khao Hin Kling area, about 50 km southwest of Phetchabun. Twenty one species within seventeen genera are described and discussed. Of them four species, *Acosarina kanmerai*, *Orthotetina ruchae*, *Haydenella granti* and *Notothyris sakagami*, are newly established ones. The Khao Hin Kling brachiopod fauna ranges from the Middle to early Late Permian. The faunal elements contain close affinities to those of the central and southern Tethyan realms.

Keywords Permian brachiopods, North-central Thailand, Tak Fa Formation, Central and Southern Tethyan Realms.

Introduction

In 1963 YANAGIDA fortunately had an opportunity to study a small collection of Permian brachiopods from north-central Thailand. It was provided by the late Dr. Teiichi KOBAYASHI, Professor Emeritus of the University of Tokyo, to whom the materials were submitted by the Department of Mineral Resources of Thailand to know their geologic age. The specimens were very well preserved in black mudstone often with natural luster of the shell surface. YANAGIDA (1964) described seven species among six genera and referred the age of the brachiopod fauna to the lower part of the *Yabeina-Lepidolna* zone of the fusuline zonation. The locality of this fauna is completely included in the present surveyed area, but unfortunately the exact localities are not confirmed, owing to insufficient field data.

In 1979 we had an occasion of visiting the Khao Hin Kling area with Dr. S. SAKAGAMI and Mr. A. HATTA, where the brachiopod materials were collected. In 1986 YANAGIDA could have a project team for the biostratigraphic study of the Paleozoic and Mesozoic in central and northern Thailand, financially supported by the Overseas Scientific Research Fund of Ministry of Education, Science and Culture of the Japanese government. The interim report of the research project was made by the Research Group (YANAGIDA (ed.), 1988).

This study covers description of brachiopods from the Khao Hin Kling area,

about 50 km SSW of Phetchabun with Highway 21 at about 15 km E of the surveyed area. This is a part of the results of study of our research project.

Geologic Outline of the Khao Hin Kling Area

The Khao Hin Kling area is covered by the Tak Fa Formation of the Permian Rat Buri Group (NAKORNSRI, 1976, 1981) or the Saraburi Limestone of the Saraburi Group (BUNOPAS, 1981). Geologically this area holds a part of the Loei-Phetchabun fold belt which is regarded as a late Paleozoic orogenic belt developed along the western margin of the Indochina Block (BUNOPAS, 1981). In the surveyed area the strata are fossiliferous and they consist mainly of bedded to massive limestones in the upper part, and alternation of dark limestones and black mudstones, and black to brown shale intercalated with fine sandstones in the lower part. The lithofacies in the lower part is variable both laterally and vertically. The general trend of the strata is also variable. In southern hills of the surveyed area, the general trend of strata shows NE-SW direction with northwestward dip. In northern area, to the contrary, it is represented by northwestward strike and southwestward dip.

Brief Notes on Localities, Accompanied Fossils and Ages of Brachiopods

Fossil localities in the Khao Hin Kling area are shown by 23 points on the accompanied map (Fig. 1) with alphabetical symbols (A-W). Of them the brachiopods occur at 7 localities as follows (Original locality number is shown in parentheses).

Locality A (860809-01): About 7.3 km west of Highway 21; abundant brachiopods in muddy part of dark impure limestone; *Orthis rucha*, n. sp., *O.* sp., *Cleiothyridina* sp., *Permophricodothyris*? sp. A and *Permophricodothyris*? sp. B accompanied by abundant bryozoans, smaller foraminifers and some gastropods. Age of brachiopods referable to middle Guadalupian to early Lopingian.

Locality H (790807-02): Thick bedded fossiliferous limestones exposed near junior school at northwestern margin of surveyed area. Brachiopods completely silicified; *Acosarina kanmerai*, n. sp., *Schuchertella* cf. *cooperi* GRANT and *Marginifera drastica* GRANT. Age of brachiopods referable to late Guadalupian.

Locality L (860810-03): Bedded black limestones with thin intercalations of black mudstones near top of small hill located in southeastern margin of surveyed area; *Tyloplecta* cf. *nankinensis* accompanied by bryozoans and fusulines (*Nankinella*? sp.). Age of brachiopods referable to late Maokouan.

Locality N (860810-01): Black limestones in alternation with black mudstones on eastern slope of small hill along up stream of Khlong Khon Kaen river at southeastern margin of surveyed area; *Orthis* sp. A, *Orthis* sp. B and *Meekella* aff. *arakeljani* (SOKOLSKAJA). Age of brachiopods referable to late Guadalupian to early Lopingian.

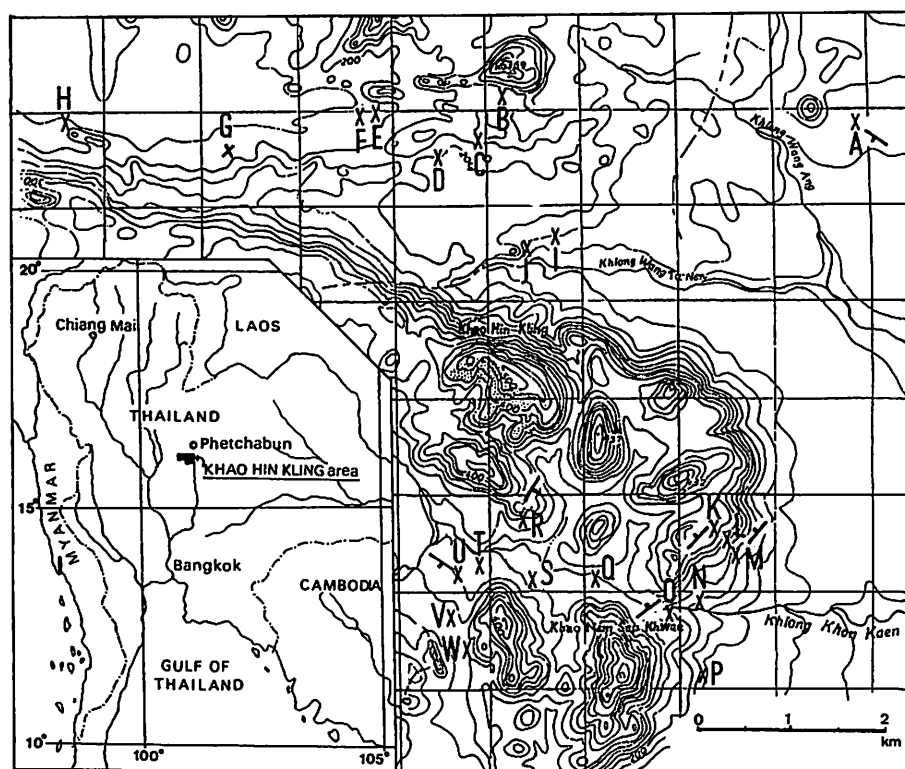


Fig. 1. Map showing the localities for the brachiopod and other fossil collections and general strike and dip of the Tak Fa Formation in the Khao Hin Kling area (after the Research Group, 1988).

Locality O (860811-03,05): Calcareous fine sandstones at foot of hill, Khao Nam Sap Khwae, about 700 m west of locality N; *Eolyttonia* sp. (860811-05) and *Haydenella granti*, n. sp. (860811-03) accompanied by bryozoans. Age of brachiopods possibly referable to middle Guadalupian (Wordian).

Locality R (860813-01): Bedded dark fossiliferous limestones often with nodulose chert distributed on hill at about 3 km south of Khao Hin Kling hill; *Orthotichia* sp. A, *Hustedia ratburiensis* WATERHOUSE and PIYASIN, *Callispirina* aff. *austriana* GRANT, *Araxathyris* cf. *araxensis* GRANT and *Notothyris sakagami*, n. sp. accompanied by bryozoans, fusulines (including *Schubertella* sp.) and coral. Age of brachiopods referable to late Guadalupian to early Dzhulfian.

Locality T (860813-02): Bedded dark fossiliferous limestones distributed at western margin of surveyed area; *Orbicoelia* aff. *extima* (GRANT), *Marginifera drastica* GRANT, *Linoproductus* sp. and *Tyloplecta* sp. accompanied by bryozoans and fusulines (schwagerinids and *Nankinella* sp.). Age of brachiopods referable to late Guadalupian.

As far as a small brachiopod fauna formerly described by YANAGIDA (1964) is concerned, the exact localities were not confirmed. However, it is strongly suggested that the localities may be at slightly northwest of the present locality O. The small brachiopod fauna is composed of *Tyloplecta yangtzeensis* (CHAO), *T. nankingensis* (FRECH), *Haydenella kiangsiensis* (KAYSER), *Marginifera banphotensis* YANAGIDA, *Orthotetina phetchabunensis* YANAGIDA, *Orthotichia javanapheti* YANAGIDA and *Linoproductus* sp. The age of the fauna was referred to the early Dzhulfian.

Table 1. Distribution of the brachiopod fossils in the Khao Hin Kling area.

Species	Localities						
	A	H	L	N	O	R	T
<i>Acosarina kanmerai</i> , n. sp.		○					
<i>Orthotichia</i> sp. A.				○		○	
<i>Orthotichia</i> sp. B.				○			
<i>Schuchertella</i> cf. <i>cooperi</i> GRANT		○					
<i>Meekella</i> aff. <i>arakeljani</i> (SOKOLSKAJA)				○			
<i>Orthotetina ruchae</i> , n. sp.	○						
<i>Orthotetina</i> sp.	○						
<i>Hustedtia ratburiensi</i> WATERHOUSE and PIYASIN.						○	
<i>Callispirina</i> aff. <i>austrina</i> GRANT.						○	
<i>Cleiothyridina</i> sp.	○						
<i>Araxathyris</i> cf. <i>araxensis</i> GRUNT						○	
<i>Permophricodothyris</i> ? sp. A	○						
<i>Permophricodothyris</i> ? sp. B	○						
<i>Orbicoelia</i> aff. <i>extima</i> (GRANT)							○
<i>Haydenella granti</i> , n. sp.					○		
<i>Marginifera drastica</i> GRANT		○					○
<i>Eolyttonia</i> sp.					○		
<i>Linoproductus</i> sp.							○
<i>Tyloplecta</i> cf. <i>nankingensis</i> (FRECH)			○				
<i>Tyloplecta</i> sp.							○
<i>Notothyris sakagami</i> , n. sp.						○	

Characters of the Khao Hin Kling Brachiopod Fauna

Affinities within Thailand: The Khao Hin Kling Permian brachiopods have large similarities to those at the seven localities in the Rat Buri Limestone of southern Thailand. They were described and discussed by WATERHOUSE and PIYASIN (1970) and YANAGIDA (1970) from Khao Phrik, west of Rat Buri, and by GRANT (1976) from the six localities, from Ban Kao, about 30 km west of Kanchanaburi, down south to the Ko Muk Island on the Andaman Sea along southern peninsula.

Orthotichia sp. A is very close to *O. waterhousei* GRANT from Khao Chang, about 15 km south of Rat Buri. GRANT noticed that *O. waterhousei* closely resembles *Orthotichia corallina* (WAAGEN) from the Kalabagh Member of the Wargal Limestone, the Salt

Range. *Schuchertella* cf. *cooperi* is comparable to *S. cooperi* GRANT. This species was originally described from Ko Muk. *Meekella* aff. *arakeljani* also resembles *M. addicta* GRANT from Ko Muk. *Hustedia ratburiensis*, originally described from Khao Phrik by WATERHOUSE and PIYASIN, is also common from Ko Muk and Khao Tok Nam near Khao Phrik (GRANT, 1976). GRANT noticed that *Hustedia ratburiensis* strongly resembles *Hustedia sulcata* REED and some specimens of *Hustedia indica* (WAAGEN) from the Amb Formation of the Salt Range. *Callispirina* aff. *austrina* is closely comparable with *C. austrina* GRANT from Ko Muk and Phangnga. *Permophricodothyris*? sp. A is similar to *Anomaloria glomerosa* GRANT from Ko Muk. *Permophricodothyris*? sp. B resembles *P. notialasiatica* GRANT from Phangnga. GRANT noticed similarity between the latter species and *P. lineata* (MARTIN) by WAAGEN from the Amb Formation, the Salt Range. *Marginifera drastica* GRANT is well known from Phangnga. *Eolyttonia* sp. is related to *E.*? sp. from Ko Muk.

It was well examined and noticed by WATERHOUSE and PIYASIN (1970) and GRANT (1976) that the Permian brachiopod faunas from several localities in southern Thailand embrace many specific elements which are closely related to those of the Permian of the Salt Range, West Pakistan. GRANT (1976) referred the age of the faunas from southern Thailand to the Artinskian based on the opinion that they are closely comparable with those of the Amb Formation of the Salt Range. YANAGIDA (1970) also considered the age of the Khao Phrik brachiopods to the Artinskian. WATERHOUSE and PIYASIN (1970) showed a different consideration on the age of the Khao Phrik brachiopods, referring to the Kazanian.

According to the recent knowledge on biostratigraphy of the Zaluch Group of West Pakistan, it became apparent that the conodonts from the Amb Formation clearly indicate a Wordian (middle Guadalupian, Kazanian) age (WARDLOW and POGUE, 1995). Taking the faunal character of the conodonts from the Amb Formation into consideration, the age of brachiopods from southern Thailand is possibly referable to the middle Guadalupian.

WATERHOUSE (1983) described a late Permian lyttoniid fauna from the Huai Tak Formation, northwest Thailand. Of the brachiopods following four species are common in genera to the Khao Hin Kling fauna: *Acosarina antesulcata* WATERHOUSE, *Meekella kueichowensis* HUANG, *Orthotetina* sp., *Araxathyris* cf. *bisulcata* LIAO. *Acosarina antesulcata* is distinct from *A. kanmerai* in having an elongate form and anterior sulcus in both valves. *Meekella kueichowensis* is too poorly preserved to compare with the Khao Hin Kling species. *Orthotetina* sp. is much smaller than *O. ruchae* and *O.* sp. of the Khao Hin Kling fauna. *Araxathyris* cf. *bisulcata* is easily distinguishable from *A. araxensis* by the size, outline and anterior commissure.

Affinities outside Thailand: The Khao Hin Kling fauna contains in its specific elements some strongly related species to those of the south China fauna.

The occurrence of 3 species of *Tyloplecta* shows a close faunal relation between the central Thailand and south Chinese province. In the Khao Hin Kling area

Tyloplecta yangtzeensis and *T. nankingensis* are already known (YANAGIDA, 1964), and this time *Tyloplecta* cf. *nankingensis* and *T. sp.* are confirmed again from the localities (respectively from L and T) very close to the former localities. *Tyloplecta* sp. is fragmentary but well shows an elongated subquadrate outline and strongly costate venter with nodes on costae. It is indicated that a close relation is recognizable between *T. sp.* and *T. costiferinoides* from the Maokouan of Guizhou (FONG, 1978). According to YANG and others (1997), *Tyloplecta nankingensis* is one of the representative species of the upper Maokouan and *T. yangtzeensis* is one of the most important species of the Upper Permian Wuchiapingian. LIANG (1990) described *T. yangtzeensis* from the upper Maokouan Lengwu Formation in the Zhejiang province. Summarizing the occurrences of *Tyloplecta* in the Khao Hin Kling area, the age of 3 species will probably be referable to the late Maokouan.

Haydenella granti has resemblance to the costate group of *H. kiangsiensis* (KAYSER), the type species of this genus, from the "Lyttonia" bed of the Lopingian, south China. Exact age of *H. granti* is not confirmed at present. *Orthotetina ruchae* is related to *O. emaciatus* CHING and YE from the Upper Permian of the Chinghai province, northwest China. *Orthotetina* sp. is similar to *O. mutabilis* LIANG from the upper Maokouan Lengwu Formation, Zhejiang province, southeast China. *Araxathyris araxensis* GRUNT is well known from the lower Upper Permian Lontan Formation of Guizhou, south China (LIAO, 1980) and the Upper Permian of northwest Chinghai province (CHING *et al.*, 1979). It is also known from the upper Maokouan Lengwu Formation of the Zhejiang province (LIANG, 1990).

Cleiothyridina sp. is similar to *Cl.?* *saraiensis* REED from the Middle *Productus* Limestone (Wargal Formation) of the Salt Range (REED, 1944). *Orbicoelia* aff. *extima* is closely related to *O. extima* GRANT from the Upper Permian Chhidru Formation, West Pakistan. *Notothyris sakagami* is closely related to *N. praelecta* REED from the Middle to Upper Permian of the Salt Range and *N. ghundiensis* REED from the Middle Permian of West Pakistan (REED, 1944).

Orthotichia sp. B well resembles *O. avushensis* from the Middle Permian Gnishikian of Armenia (SOKOLSKAJA, 1965). *Meekella* aff. *arakeljani* is closely related to *M. arakeljani* (SOKOLSKAJA) from the upper Middle Permian Huchikian, Armenia. *Araxathyris* cf. *araxensis* is closely comparable with *A. araxensis* GRUNT from the Upper Permian Dzhulfian (*Araxilevis* zone) of the Caucasus. It is also known from the Upper Permian Nesen Formation of north Iran (SESTINI, 1966).

Systematic Description

Superfamily Enteletacea WAAGEN, 1884

Family Schizophoriidae SCHUCHERT and LEVENE, 1929

Genus *Acosarina* COOPER and GRANT, 1969

Type-species: *Acosarina dorsisulcata* COOPER and GRANT, 1969

Acosarina kanmerai, n. sp.

Pl. 26, Figs. 1–7

Material and Locality: Lots of complete and incomplete specimens are at hand. The holotype, KMNH IvP 610,001 (Pl. 26, Fig. 6), shows a slightly younger stage of growth. Internal structures are well shown by some disarticulated or partly broken articulated valves (Locality H).

Description: Average size for genus, subcircular to subquadrate in outline, slightly wider than long with largest width at midlength; hinge much shorter than largest width; lateral profile slightly dorsi-biconvex. Anterior commissure slightly sulcate. Surface multicostellate, about 4 to 5 costellae in distance of 1 mm on anterior half.

Pedicle valve less convex than brachial one with largest convexity at slightly posterior to midvalve; median anterior half nearly flat. Umbonal region slightly swollen with projected beak. Interarea slightly concave with apsacline to nearly catacline profile to commissural plane. Hinge line about a half length of largest width of valve. Delthyrium open and conspicuous.

Brachial valve strongly and evenly convex in lateral profile with largest convexity at midvalve; anterior profile domed with median part flattened or slightly and broadly sulcated; flanks swollen and rather steep-sided; sulcus broad, shallow but distinct; notothyrium small and open.

Pedicle valve interior with short, flaring dental plates; median septum low but long, extending anteriorly for about midlength of valve. Brachial valve interior with short divergent brachiophores, small sockets and brachiophore supports. Cardinal process small.

Dimensions of 7 specimens as follows (in mm):

	length (ped.v.)	length (br.v.)	width	length of hinge line	thickness
KMNH IvP 610,001 (holotype)	11.1	11.1	13.1	7.0	7.2
610,002	13.2	13.1	16.0		8.0
610,003	11.6	12.0	13.9	7.6	7.5
610,004	9.5	9.7	11.5	5.8	6.2
610,005	9.1	9.2	11.1	5.2	5.8
610,006	ca. 12	ca. 12	14.0	7.0	8.0
610,007			14.6	5.9	8.5

Remarks: *Acosarina kanmerai*, n. sp. is characterized by subcircular to transversely subelliptical outline and by having a distinct and shallow sulcus in the brachial valve. Therefore the anterior commissure reveals a slightly sulcate form. From the viewpoint of the latter character this species is similar to *Acosarina dorsisulcata* from the Lower Permian Bone Spring Limestone, western Texas (COOPER and GRANT, 1969). However, it differs from the latter by its wider outline, less inflated valves and strongly inclined interarea of the pedicle valve.

In Thailand WATERHOUSE (1983) described *Acosarina antesulcata* from a mudstone of the Huai Tak Formation in the Doi Pha Phlung area, northwest Thailand. The figured specimen of the holotype shows elongate oval outline and other figured specimens are more or less deformed and almost all of them are the internal moulds. WATERHOUSE paid attention to the presence of a ventral sulcus in *A. antesulcata*. Therefore, it is clearly distinguished from the present species. *Orthotichia waterhousei* GRANT from the Middle Permian of the Rat Buri Limestone in Khao Chang and Khao Tok Nam, the southern peninsular area of Thailand (GRANT, 1976), is similar to *Acosarina kanmerai* in its general characters. The most conspicuous difference between them, however, is the existence of a dorsal sulcus in the latter.

The Salt Range species, *Orthis indica* WAAGEN, is often treated as *Acosarina*. GRANT (1976), however, emphasized the importance of the ventral sulcus in the Salt Range species, *Orthis indica*. He examined it by the topotype materials from the Amb Formation. However, WAAGEN (1883) clearly described existence of the dorsal sulcus and his figured specimens well reveal the character. Therefore the generic position of *O. indica* is referable to *Acosarina* without doubt.

LIANG (1990) described a species under the name of *A. indica* (WAAGEN) from the upper Middle Permian Lengwu Formation in the Zhejiang province, south China. Although the Zhejiang specimen is represented by an internal mould of conjoined shell, it shows a shallow and broad dorsal sulcus and the general characters are similar to *A. kanmerai*. The Zhejiang species, however, may be distinguishable from *A. kanmerai* by its more inflated and larger shell. YANAGIDA (1964) described a new species of *Orthotichia*, *O. javanapheti* (= now it is referred to *Acosarina*) from a black mudstone in the surveyed area. That species has an elongate oval outline, inflated valves, and a broad shallow sulcus in the dorsal valve. These characters easily distinguish *A. javanapheti* from *A. kanmerai*.

The new species is named after Dr. Kametoshi KANMERA, Professor Emeritus of Kyushu University, who greatly contributed to establish the fusuline biostratigraphy of the Rat Buri Limestone with the late Dr. TORIYAMA.

Genus *Orthotichia* HALL and CLARKE, 1892

Type-species: *Orthis? morganiana* DERBY, 1874

Orthotichia sp. A

Pl. 26, figs. 8 and 9

Material and Locality: Three conjoined and silicified shells, KMNH IvP 610,011, 610,012, 610,013 are at hand (Locality N and R).

Descriptive remarks: Shell medium for genus, slightly wider than long with subrounded outline; hinge much shorter than width, largest width at midvalve. Pedicle valve slightly convex, flattened or broadly depressed on median anterior half and narrowly swollen posteriorly; beak weakly projected on slightly concave low interarea with apsacline profile to commissural plane; delthyrium open; valve surface ornamented by fine costellae, increasing in number by intercalation, about 4 to 5 in distance of 1 mm near anterior margin; anterior commissure rectimarginate with very slight arch. Brachial valve smoothly and slightly more convex than opposite valve longitudinally, beak region broken, neither sulcus nor depression distinguished on median surface; surface ornamentation as same as pedicle valve.

Pedicle valve interior with partly observed median ridge and dental plates. Brachial valve interior with partly preserved brachiophore supporting plates, extending at about a third length from beak.

Dimension of better preserved specimen, KMNH IvP 610,011, as follows (in mm): length (ped. v.), ca 14; length (br. v.), ca 14; width, 10; thickness, 8.8; length of hinge line, 5.9.

The Khao Hin Kling specimens with conjoined valves are characterized by having slightly less convex pedicle valves with nearly flattened anterior half, nearly rectimarginate or slightly arched anterior commissure without any suggestion of dorsal depression. In these characters the present species seems to be very close to *Orthotichia waterhousei* described by GRANT (1976) from the Middle Permian of Khao Chang, southern Thailand. The Khao Hin Kling species, however, may be distinct from *O. waterhousei* in having the more transverse outline.

Orthotichia sp. B

Pl. 26, fig. 10

Material and Locality: A partly broken conjoined specimen, KMNH IvP 610,014, is available with the following dimension (in mm): length (br.v.), 17.5; width, ca 18; thickness, ca 12 (Locality N).

Descriptive remarks: Shell large for genus, rounded subtriangular to subpentagonal in outline with widest part at slightly anterior to midvalve; both valves moderately convex, brachial valve slightly larger than pedicle valve in convexity. Surface of both valves ornamented by costellae, about 5 costellae in 1 mm on anterior half, increasing in number anteriorly by intercalation, larger ones disposed in interval of about 1 mm. Anterior commissure rectimarginate.

Conspicuous characters of the present species are in its subtriangular outline, moderately convex brachial valve and rectimarginate commissure. These characters of the Khao Hin Kling species well resemble those of *Orthotichia avushensis* described by SOKOLSKAJA (in RUZHENTSEV and SARYCHEVA, 1965) from the Middle Permian Gnishikian in Armenia. However, the Thailand species is slightly larger than the latter.

Superfamily Orthotetacea WAAGEN, 1884
 Family Schuchertellidae WILLIAMS, 1953
 Subfamily Schuchertellinae WILLIAMS, 1953
 Genus *Schuchertella* Girty, 1904

Type-species: *Streptorhynchus lens* WHITE, 1862

Schuchertella cf. *cooperi* GRANT, 1976

Pl. 27, figs. 1–8

cf.

1976. *Schuchertella cooperi* GRANT. p. 42, pl. 4, figs. 1–41, pl. 6, figs. 1–12.

Material and Locality: Most of the available specimens are fragmentary and silicified ones ranging from younger to adult stages of growth. (Locality H).

Description: Shell average size for genus; outline transversely subquadrate; hinge line slightly shorter than largest width which normally locates at midvalve, hinge margin sometimes extends slightly.

Pedicle valve very shallowly conical posteriorly on anterior half, however, it rapidly becomes flattened; interarea low with profile of apsacline to commissural plane; pseudodeltidium slightly arched; pedicle valve surface covered by costellae, increasing in number generally by intercalation, very rarely by bifurcation, about 9 to 11 costellae in 5 mm on anterior half; growth wrinkles rather common arranged in irregular distances and fine growth lines sometimes visible.

Pedicle valve interior with stout teeth supported by low dental ridges along inner margins of pseudodeltidium; median ridge is very low and short, only recognizable in beak region; muscle area obscure, valve floor ornamented by radial striation, reflecting external costellae, generally stressed near anterior margin.

Brachial valve interior with low and wide cardinal process, myophores low; muscle area narrow and obscurely marked; sockets rather deep with recurved socket plates, crural plates short and slightly project anterolaterally; ornamentation on valve floor as same as opposite valve.

Dimensions of 3 incomplete specimens as follows (in mm):

	length (ped.v.)	width	length of hinge line	length (br.v.)
KMNH IvP 610,015	ca. 15	19.5	16.5	
610,016		ca. 19	ca. 16	13.8
610,017	7.0	9.0	8.9	

Remarks: Although the present species consists of incomplete valves, it is closely comparable with *Schuchertella cooperi* GRANT from the Middle Permian of Ko Muk (GRANT, 1976), a small island on the Andaman Sea, southern Thailand. Particularly the general shell form and the internal characters of both valves of the present species are well in harmony with those of *S. cooperi*. Costellae of the former species seem to be slightly coarser than the latter. GRANT (1976) noted on the Chinese Permian species, *S. frechi* HUANG, from the Guizhou province which is one of the very few specific elements of *Schuchertella* in China. This species is distinct from the present one by its rounded outline and by having the finer costellae.

Family Meekellidae STEHLI, 1954

Genus *Meekella* WHITE and ST. JOHN, 1867

Type-species: *Plicatula striatocostata* COX, 1858

Meekella aff. *arakeljani* (SOKOLSKAJA), 1965

Pl. 27, fig. 12

Compare.

1965. *Orthotetina arakeljani* SOKOLSKAJA. p. 205, pl. 30, fig. 3 (in RUZHENTSEV and SARYCHEVA, 1965).

Material and Locality: A pedicle valve, KMNH IvP 610,020, is described under the heading with the following dimension (in mm): length, 27.2; width, 27.5; hinge line, 21.2; thickness, 12.0 (Locality N).

Descriptive remarks: Shell large for genus. Pedicle valve rounded quadrate, shallowly conical with exfoliated beak region; largest width at midvalve, hinge line much shorter than largest width; valve surface ornamented by very fine costellae and rounded radial plicae, costellae increase in number by intercalation, about 4 to 5 in 1 mm on anterior half; costae rounded and simple, pronounced in strength on antero-median surface and indistinct on both lateral slopes, about 10 plicae counted, originated in beak region; interarea narrow, low and nearly vertical or strongly inclined (apsacline) to commissural plane; irregularly disposed growth wrinkles

remarkable on lateral slopes; pseudodeltidium more or less exfoliated but suggests smoothly arched appearance. Internally teeth ridges narrow and anteriorly continuous to narrowly separated dental plates, detail of their anterior extension unknown.

Among the known species of *Meekella* the Khao Hin Kling species is very close to *Meekella arakeljani* (SOKOLSKAJA) described by SOKOLSKAJA (1965) from the upper Middle Permian Hachikian in Armenia under the name of *Orthotetina*. The Armenian species is characterized by strong plicae which are considered to be originated in early stage of growth. The size and outline of adult shell also well resemble those of the Khao Hin Kling species. The difference between them is recognizable in number of plicae, the latter has the fewer plicae than the former.

GRANT (1976) described 3 species of *Meekella* from some localities of southern Thailand. Of them *Meekella addicta* from Middle Permian of Ko Muk, southern Thailand, is also similar to the present species, especially in character of plicae. The Kho Muk species, however, is much smaller than the Khao Hin Kling one and the former has the stronger costae than the latter.

Genus *Orthotetina* SCHELLWIEN, 1900

Type-species: Orthotetes persicus (SCHELLWIEN), 1900

Orthotetina ruchae, n. sp.

Pl. 27, Figs. 9 and 11

Material and Locality: Holotype, KMNH IvP 610,023 (pedicle valve), Other two pedicle valves (KMNH IvP 610,021 and 610,022) and an incomplete brachial valve (KMNH IvP 610,024) are available (Locality A)

Description: Shell medium size for genus, subcircular in younger stage of growth and transversely subrounded in mature shell; largest width at midvalve. Pedicle valve moderately convex, convexity posteriorly larger than anterior half; hinge line much shorter than largest width, slightly shorter than a third width in younger shell; interarea rather low, slightly concave with weak incline to commissural plane (apsacine); pseudodeltidium narrow and smooth; surface ornamented by irregularly disposed, concentric broad wrinkles and fine costellae, about 7 in distance of 2 mm on anterior half in adult shell and about 5 in 1 mm in younger one, increasing in number by intercalation.

Brachial valve fragmentary, showing slightly convex valve with finely costellate surface; umbonal region very low.

Dimensions of 4 specimens as follows (in mm):

	length	width	thickness	length of hinge line	height of interarea
KMNH IvP 610,021	26.21	26.8	5.0	9.0	6.5
610,022	28.3	35.5	9.5	15.0	ca. 12
610,023	31.0	39.0	10.5	17.0	ca. 13
(holotype)					
610,024	25.8	ca. 30	ca. 6		
(brachial valve)					

Pedicle valve interior with narrowly separated parallel dental plates, continuous to teeth ridges, extremely narrowly separated in younger shell but not fused on apical floor, their anterior extension in adult shell around a half length of valve.

Remarks: *Orthotetina ruchae* is characterized by its strongly convex pedicle valve with irregular concentric wrinkles, rather low interarea with apsacline inclination and very narrow hinge. Among the known species of *Orthotetina* in Thailand, no species is closely comparable with the present one. *Orthotetina phetchabunensis* (YANAGIDA, 1964) from the Middle or Upper Permian black calcareous mudstone of the Tak Fa Formation in the Ban Phot area, about 5 km SSW of the present locality, is distinct from *O. ruchae* by having the coarser costellae, longer hinge line and less inflated pedicle valve. WATERHOUSE (1983) described *Orthotetina* sp. from the Huai Tak Formation in the Huai Tao area. This species is distinct from *O. ruchae* by having the wider hinge and higher interarea at right angle to the commissural plane. Among the Asian species of *Orthotetina*, *O. emaciatius* CHING and YE (1979) from the Upper Permian of the Chinhai province, shows very close resemblance to *O. ruchae* in its slightly transversely rounded outline, very short hinge and rounded cardinal extremities, low interarea and size. The surface of the Chinhai species also has growth wrinkles. The costellae of the Chinhai species, however, are slightly coarser and the hinge is wider than *O. ruchae*.

The new specific name is dedicated to Mrs. Rucha HELMCKE, the former Chief paleontologist of the Geological Survey Division, Department of Mineral Resources, Thailand, who made a great contribution to development of paleontology in Thailand through the study of the fusulines and corals.

Orthotetina sp.

Pl. 27, fig. 10

Material and Locality: A strongly exfoliated pedicle valve, KMNH IvP 610,025, with the following dimension (in mm) is available: width, 26.5; length, 26.1; length of

hinge line, 14.3; height of interarea, 10.3 (Locality A).

Descriptive remarks: Shell small for genus, subtriangular with largest width at anterior to midvalve, largest convexity at midvalve; beak elongately projected posteriorly; interarea narrow, high and slightly concave with weak angle to commissural plane (weakly apsacline); pseudodeltidium broad; hinge line very short, about a half length of largest width; cardinal extremities rounded; fine costellae partly observed. Pedicle valve interior with dental plates, partly broken but disposed in parallel at apex.

The pedicle valve surface of the Khao Hin Kling species is completely exfoliated. The generic identification is based on the dental plates disposed in parallel in umbonal region. Posteriorly elongated outline resembles that of *Perigeyerella costellata* WANG (1955) from the Upper Permian of Guizhou province, south China. Separated dental plates, however, distinguish the present species from those of *Perigeyerella*. LIANG (1990) described some species of *Orthotetina* from the upper Middle Permian Lengwu Formation, Zhejiang province, southeast China. Of them *Orthotetina mutabilis* has the similar form of pedicle valve to the present species, especially in the elongated beak with apsacline to orthocline inclination of interarea. *O. mutabilis* well shows asymmetrical form and the present species is also in harmony with this character. The former, however, is distinct from the latter by its much larger size.

Superfamily Retziacea WAAGEN, 1883

Family Retziidae WAAGEN, 1883

Genus *Hustedia* HALL and CLARKE, 1893

Type-species: *Terebratula mormoni* MARCOU, 1858

Hustedia ratburiensis WATERHOUSE and PIYASIN, 1970

Pl. 32, figs. 11–16

1970. *Hustedia ratburiensis* WATERHOUSE and PIYASIN, P. 138, pl. 23, figs. 15–30.

1970. *Hustedia nakornsrii* YANAGIDA, p. 79, pl. 14, fig. 9.

1976. *Hustedia ratburiensis*, GRANT, p. 241, pl. 66, figs. 1–69, pl. 67, figs. 51–58.

Material and Locality: More than 20 silicified specimens mostly with conjoined valves are available (Locality R).

Description: Shell of average size for genus but rarely attains to large; suboval to transversely subrounded in outline, widest part at slightly anterior to midlength; moderately biconvex with nearly equal convexity; pedicle valve with slightly projected beak; foramen small, circular and mesothyridid; interarea low; deltidial plates fused at midline; surface of pedicle valve costate; costae rounded, simple, originating at beak, rapidly increasing in width anteriorly, about 10 costae on pedicle valve and 11

on brachial valve, crest of costa and intertrough rounded; central 2 costae on pedicle valve produce narrow sulcus, median costa on brachial valve, on the other hand, produces low and narrow fold.

Pedicle valve interior with stout hinge teeth partly observed in fragmentary valve. Brachial valve interior with incompletely preserved spirulum, some 7 whorls observed, suggesting laterally extended axis. Other internal structures unknown.

Dimensions of 6 specimens as follows (in mm):

	length	length (br.v.)	width	thickness	number of costae (br.v)
KMNH IvP					
610,026	11.0	8.5	10.8	ca. 5	11
610,027	8.7	7.3	7.1	5.3	11
610,028	8.0	6.7	7.3	4.5	9
610,029	8.9	7.4	7.6	5.5	11
610,030	8.6	6.7	8.2	5.5	12
610,031	7.4	7.1	6.4	4.4	11

Remarks: *Hustedia ratburiensis* was first described by WATERHOUSE and PIYASIN (1970) based on several silicified specimens from the Middle Permian of the Khao Phrik area of southern Thailand. GRANT (1976) described the same species by a huge number of silicified specimens from Ko Muk and many well preserved specimens from Khao Tok Nam, about 6 km south of Khao Phrik. The specific discussions were done in great detail by them. GRANT (1976) noticed on the size of *Hustedia ratburiensis* which attains larger than those shown by WATERHOUSE and PIYASIN (1970). The Khao Hin Kling specimens are well in harmony with the Ko Muk and Khao Tok Nam specimens as far as their size character is concerned.

Superfamily Spiriferinacea DAVIDSON, 1884

Family Spiriferinidae DAVIDSON, 1884

Genus *Callispirina* COOPER and MUIR-WOOD, 1951

Type-species: *Spiriferina ornata* WAAGEN, 1883

Callispirina aff. *austrina* GRANT, 1976

Pl. 28, fig. 1.

Compare.

1976. *Callispirina austrina* GRANT. p. 231, pl. 63, figs. 1-37.

Material and Locality: Longitudinally half missing conjoined specimen, KMNH IvP 610,032, with the following dimension is at hand: length, 10.5 mm; length (br.v.), 7.5 mm; width, ca 11 mm; thickness, 7.0 mm (Locality R).

Descriptive remarks: Shell medium size for genus; outline subglobular with moderately convex valves, hinge line slightly shorter than largest width which locates at slightly anterior to hinge line; cardinal extremities rounded. Pedicle valve strongly convex with incurved beak; interarea narrow, delthyrium open; sulcus broadly v-shaped in transverse profile with narrow but smooth bottom, a pair of very low obscure ridges on slopes near bottom, probably bifurcated from sulcus-bounding costae in umbonal region; 5 narrow simple costae on each side of pedicle valve, width of costae and intercostal furrows nearly same; surface of pedicle valve covered by regularly arranged fine growth laminae; minute and densely scattered pustules partly observable. Brachial valve moderately convex with high fold and 5 distinct costae on each side of brachial valve. Internal structures unknown.

The Khao Hin Kling specimen is characterized by having the strongly biconvex valves with rotund form, large sulcus and distinct sulcus-bounding costae. Other lateral costae make a sharp contrast with the bounding costae in strength. It is also characterized by closely spaced growth laminae on the surface of valve. Although the present specimen is incomplete, these external characters well reveal those of *Callispirina* and specifically it seems to be very close to *Callispirina austrina* described by GRANT (1976) from the Middle Permian of Ko Muk, southern Thailand. The Khao Hin Kling species, however, differs from *C. austrina* by its fewer costae and by a pair of very weak ridges on the lower slopes of sulcus.

Superfamily Athyridacea M'COY, 1844

Family Athyrididae M'COY, 1844

Genus *Cleiothyridina* BUCKMAN, 1906

Type-species: *Spirifer deroissyi* LÉVEILLÉ, 1835

Cleiothyridina sp.

Pl. 28, figs. 2–6

Material and Locality: Six incomplete specimens, two conjoined valves (KMNH IvP 610,033 and 610,034), three pedicle valves (KMNH IvP 610,035–610,037) and a brachial valve (KMNH IvP 610,038) are available (Locality A).

Descriptive remarks: Shell medium for genus; outline variable, transversely subcircular to slightly elongated oval with widest part at midlength; both valves moderately convex. Pedicle valve normally with long beak, foramen minute; sulcus very shallowly and broadly located near anterior margin; anterior commissure slightly uniplicate; surface covered by tightly arranged concentric lamellae, about 10 to 15 in

distance of 5 mm near anterior margin, minute spine bases occasionally recognizable on lamellae. Brachial valve with swollen umbo; beak very close to that of opposite valve; median anterior margin slightly raised.

Dimensions of 6 specimens as follows (in mm):

	length (ped.v.)	length (br.v.)	width	thickness
KMNH IvP				
610,033	17.2	15.6	17.5	9.0
610,034	16.3	15.6	ca. 16	10.2
610,035	17.0		ca. 15	ca. 7 (ped.v.)
610,036	ca. 15		17.0	ca. 5 (ped.v.)
610,037	18.0		20.9	ca. 6 (ped.v.)
610,038		18.5	20.0	ca. 7 (br.v.)

Internal characters only discriminated by pallial markings in pedicle valve, about 8 longitudinally parallel simple grooves marked on valve floor, anteriorly they suddenly decrease strength.

The present specimens are very poorly preserved and then the details of microsculpture of the shell surface are only recognized as the trace. An unfortunate state of preservation of spines on the concentric lamellae probably depends on their originally short and small nature. Very strongly marked pallial markings are characterized by the simple grooves which are nearly parallel to the median longitudinal axis of the pedicle valve as COOPER and GRANT (1976) remarked them in discussion of *Cleiothyridina*. The pallial markings are shown by a dorsal valve interior of *Cleiothyridina pilulalis* from the Permian of the Bell Canyon Formation of West Texas (pl. 650, fig. 80).

The Khao Hin Kling specimens externally resemble those of *Cleiothyridina seriata* from the Middle Permian of some places in southern Thailand (GRANT, 1976). The distinct characters between them are the existence of the simple grooves of pallial markings in the former specimens. The forams of pedicle valves within the Khao Hin Kling specimens are minute and very difficult to discriminate them. Among the athyridids described by REED (1944), some species such as *Cleiothyridina? saraiensis* from the Middle? Productus Limestone (upper Guadalupian) resembles the present species in general outline and in having the pallial markings though the Salt Range species is much larger in number of grooves.

Genus *Araxathyris* GRUNT, 1965

Type-species: Spirigera protea ABICH, 1878

Araxathyris cf. araxensis GRUNT, 1965

Pl. 28, fig. 13; Pl. 29, fig. 4

cf.

1965. *Araxathyris araxensis* GRUNT. p. 248, pl. 43, figs. 6a, b (in RUZHENTSEV and SARYCHEVA, 1965)1966. *Araxathyris araxensis*, SESTINI and GLAUS. p. 910, pl. 65, fig. 6.1978. *Araxathyris araxensis*, TONG. p. 249, pl. 87, figs. 3, 4.1979. *Araxathyris araxensis*, CHING, YE, XU and SUN. p. 122, pl. 34, figs. 5–12.1980. *Araxathyris araxensis*, LIAO. p. 267, pl. 9, figs. 35–37, text-fig. 1.1990. *Araxathyris araxensis*, LIANG. p. 266, pl. 49, figs. 1–5, pl. 80, fig. 26.

Material and Locality: A conjoined immature specimen (KMNH IvP 610,053), and a conjoined but partly damaged adult one (KMNH IvP 610,054) are available (Locality R).

Descriptive remarks: Shell small for genus; subrounded to subovoidal in outline; length nearly as wide as shell; largest width at midlength; hinge line much shorter than largest width, slightly larger than half of largest width; anterior commissure episulcate in mature specimen and rectimarginate in immature specimen.

Pedicle valve mostly damaged, only beak region, lateral and anterior regions well preserved; umbonal region strongly convex with distinct foramen; anterior margin with linguiform broad extension of sulcus; both lateral side of sulcus broad folds suggested by anterior wavy commissure; pedicle valve suggested to moderately inflated. Brachial valve moderately convex both longitudinally and transversely; median broad fold anteriorly conspicuous with very shallow median depression on fold, originating near umbonal region; a pair of broad incipient radial elevation on each outer side of broad fold; both valves ornamented by very fine growth lines. Immature specimen characterized by moderately biconvex shell; both valves with distinct sulcus originating at slightly anterior to umbonal region; incipient fold recognizable on anterior half of brachial valve; anterior commissure rectimarginate.

Dimensions of 2 specimens as follows (in mm):

	length	width	thickness	length of hinge line
KMNH IvP 610,053	7.3	7.2	4.5	4.3
610,054	13.4	12.6	9 +	8.8

Although the Khao Hin Kling specimens are incomplete, the external characters are strongly similar to those of the holotype specimen of *Araxathyris araxensis* from the Upper Permian Dzhulfian (*Araxilevis* zone) of the Caucasus. The present mature specimen is also comparable to that of *A. araxensis* from the Upper Permian Nesen Formation of North Iran (SESTINI and GLAUS, 1966).

Araxathyris araxensis is widely distributed in China, stratigraphically ranging from the Middle Permian Maokouan to Upper Permian Lopingian. In Thailand WATERHOUSE (1983) described *Araxathyris* cf. *bisulcata* LIAO from the Upper Permian of the Huai Tak and Doi Pha Phlung areas, northwest Thailand. However, it is poorly preserved and seems to be clearly distinct from the present species.

Superfamily Reticulariacea WAAGEN, 1883
Family Elythidae FREDERIKS, 1919 (1924)
Genus *Permophricodothyris* PAVLOVA, 1965

Type-species: *Permophricodothyris ovata* PAVLOVA, 1965

Remarks: The generic position of the Khao Hin Kling specimens is in doubt because their delthyrial characters are unknown at all. They have delicate character of spine bases in row on each lamella of the shell surface. However, it is highly possible that *Permophricodothyris* sp. A will be transferable to *Anomaloria* or *Astegosia*, if the delthyrial character is confirmed.

Permophricodothyris? sp. A
Pl. 28, figs. 7–9

Material and Locality: More than 15 slightly deformed small specimens are available (Locality A).

Descriptive remarks: Shell small size for genus; outline slightly variable, ranging from elongately subovoid to subcircular; widest part at midlength; hinge line much shorter than largest width; biconvex with same convexity to opposite valve.

Pedicle valve moderately convex with short beak; interarea not preserved and suggested to very small; surface ornamented by regularly arranged concentric lamellae with minute spine bases or their traces near anterior margin of each lamella; 1 to 2 lamellae in 1 mm on anterior half. Brachial valve with blunt beak; surface ornamentation similar to pedicle valve.

Dimensions of 6 specimens as follows (in mm):

	length (ped.v.)	length (br.v.)	width	thickness
KMNH IvP				
610,039	15.4		15.2	ca. 6
610,040	7.5		7.5	ca. 2.5
610,041	15.3		13.5	ca. 4.3
610,042	11.0		11.1	ca. 3.8
610,043		9.6	11.5	ca. 2.8
610,044		7.8	7.2	ca. 1.8

The Khao Hin Kling specimens are characterized by the small equilateral outline, and rather weakly convex both valves with regularly arranged concentric lamellae and minute spine bases disposed tightly in row at the anterior margin of each lamella. In these characters especially in outline, the present specimens well resemble those of *Anomaloria glomerosa* GRANT (1976) from the Middle Permian of Ko Muk, southern Thailand. The Ko Muk specimens are all silicified and characters of the deltidial plates are well recognized even in the very small specimens. GRANT (1976) described *Astegosia?* sp. with *Anomaloria* from the same locality. The described specimens are moderately different from the present ones. However, if the present specimens have the open delthyrium, then they are externally very close to *Astegosia subquadrata* (GIRTY), the type species of this genus from the Lower Permian of the Guadalupe Mountains. Such being the case the writers would like to treat the Khao Hin Kling species under the generic name of *Permophricodothyris* with question at present.

Permophricodothyris? sp. B

Pl. 28, figs. 10–12

Material and Locality: Several incomplete specimens are available. Of them 2 conjoined shells, 3 pedicle valves and 2 brachial ones are the better preserved valves (Locality A).

Descriptive remarks: Shell small for genus; outline transversely subcircular, weakly biconvex; anterior commissure rectimarginate to very rarely weakly folded; hinge line much shorter than largest width, both valves ornamented by weak concentric lamellae with very fine spine bases or exfoliated, longitudinally parallel striae of traces of spine bases on each lamella.

Dimensions of 5 specimens (in mm):

	length (ped.v.)	length (br.v.)	width	thickness
KMNH IvP				
610,047	10.5	10.5	15.1	7.2
610,048	14.5		18.0	ca. 7.5
610,049	12.9		16.5	ca. 4.4
610,050	10.0		12.8	ca. 3.0
610,051		10.0	11.5	ca. 2.0

Permophricodothyris? sp. B is distinguished from *Permophricodothyris?* sp. A by its slightly larger size, more or less transverse outline and less inflated valves. Each lamella of *P.?* sp. A seems to be more distinct than *P.* sp. B. *Permophricodothyris notialasiatica* GRANT from the Middle Permian of Phangnga, southern Thailand (GRANT, 1976), resembles the present species in external characters. The detailed

comparison is difficult owing to the poor state of preservation of the present species. Among the figured specimens of *Phricodothyris attenuata* by WATERHOUSE and PIYASIN (1970) from the Middle Permian of Kao Phrik, southern Thailand, figs. 7 and 9 strongly resemble the present specimens in external characters.

Superfamily Cyrtiacea FREDERIKS, 1924
Family Ambocoeliidae GEORGE, 1931
Genus *Orbicoelia* WATERHOUSE and PIYASIN, 1970

Type-species: *Orbicoelia fraterculus* WATERHOUSE and PIYASIN, 1970

Orbicoelia aff. *extima* (GRANT), 1970
pl. 28, fig. 14

Compare.

1970. *Crurithyris?* *extima* GRANT. p. 142, pl. 3, figs. 1–3, Text-fig. 1.

Material and Locality: Only 1, nearly completely preserved, conjoined shell, KMNH IvP 610,052, with the following dimension (in mm) is available: length, 7.4; width, 8.8; length of hinge line, 6.0; thickness, 4.9 (Locality T).

Descriptive remarks: Shell small size for genus; transversely subelliptical with blunt beak, short hinge and well rounded cardinal extremities; hinge line much shorter than largest width, slightly larger than half as wide as shell; largest width at about slightly posterior to midlength; shell ventri-biconvex in profile, pedicle valve moderately convex both longitudinally and transversely; brachial valve very weakly inflated, especially in posterior half; beak of brachial valve broken; anterior commissure rectimarginate and neither sulcus nor fold recognized on both valves; surface of both valves smooth. Interarea of pedicle valve narrow and slightly concave; delthyrium narrow and closed by deltidial plates; notothyrium of brachial valve represented by depression but not preserved. Internal characters unknown.

The genus *Orbicoelia* was established by WATERHOUSE and PIYASIN (1970) based on silicified and incomplete specimens from the Middle Permian of Khao Phrik, southern Thailand. Afterward GRANT (1976) examined the same species by excellent silicified specimens from some localities in southern Thailand and detailed comparison and discussion were given on the alliances of *Orbicoelia*. GRANT (1976) noticed that *Crurithyris?* *extima* GRANT (1970) and *Crurithyris speciosa* WANG (1956), respectively from the Upper Permian Chhidru Formation of West Pakistan and Changsingian of south China, are highly possible to be congeneric with *Orbicoelia*.

The Khao Hin Kling species is closely related to *Orbicoelia extima* in its external characters, especially in size, outline and convexities of both valves.

The only difference between the Khao Hin Kling species and the Chhidru one is

recognizable on imperceptibly uniplicate anterior commissure in the younger shells and sulcate anterior commissure in the larger shells of the latter species. Therefore the figured specimens by GRANT (1970) suggest an incipient median depression on brachial valve. *Orbicoelia speciosa* (WANG) is characterized by having rows of fine spines on the surface of both valves. The spinose character is not known at all in the Khao Hin Kling specimens. *Orbicoelia fraterculus* from Khao Phrik, Khao Chang, Khao Tok Nam, Phangnga and Ko Muk are all from the Middle Permian of southern Thailand. The most noticeable difference between *O. fraterculus* and the present *O. aff. extima* is recognized on the brachial valve convexity. The former has brachial valve more inflated than that of the latter.

Superfamily Productacea WAAGEN, 1883

Family Linoproductidae STEHLI, 1954

Subfamily Linoproductinae STEHLI, 1954

Genus *Linoproductus* CHAO, 1927

Type-species: *Productus cora* D'ORBIGNY, 1842

***Linoproductus* sp.**

Pl. 30, fig. 1

Material and Locality: An incomplete shell, KMNH IvP 610,065, with the following dimension (in mm) is available: length, 36.0; width, 32.0; height, ca. 20; thickness, ca. 12 (Locality T).

Descriptive remarks: Shell small size for genus; outline oval; profile evenly convex on visceral disc, convexity decreasing forward with long trail; venter more or less flattened; flanks rather steep with 2 or 3 very weak broad rugae; ears small, becoming flattened; costellae finely and evenly cover pedicle valve, about 5 in distance of 2 mm near anterior margin, with occasional bifurcation; spine bases very few, sporadic on trail with curved costellae around bases. Brachial valve only recognizable by partly broken anterior part of visceral disc with costellae similar to those of pedicle valve; weak rugae common. Internal structures unknown.

The Khao Hin Kling specimen is not complete in preservation but well reveals the external characters of pedicle valve. This species is characterized by its small size, strongly convex pedicle valve and finely arranged costellae. In these points it is distinct from *Linoproductus kaseli* GRANT from the Middle Permian of Phangnga, southern Thailand. *Linoproductus* sp. described by YANAGIDA (1964) from the present area, slightly distant from the locality (T) to northeast, well resembles the present species in external characters. They are probably one and the same species with each other.

Genus *Haydenella* REED, 1944

Type-species: *Productus kiangsiensis* KAYSER, 1883

Remarks: Although the generic knowledge on *Haydenella* is incomplete, the occurrence of *Haydenella kiangsiensis* KAYSER from the Upper Permian is rather common in China. The surface ornamentation is very variable in the type-species, ranging from finely capillate to costate. The common character is conspicuously marked rugae on ears disposed nearly perpendicular to the hinge line. A row of spine bases is also common on the basal part of each flank. MUIR-WOOD and COOPER (1960) pointed out that the costate specimens of *Productus kiangsiensis* KAYSER by HUANG (1932) are probably distinct from *Haydenella*. GRANT (1976) mentioned existence of a linoproductide cardinal process in *Haydenella salinaria* REED among his collected silicified specimens from the Amb Formation, West Pakistan, and he referred *Heydenella* to Linoproductidae.

The present Khao Hin Kling specimens externally well resemble the costate type of *Haydenella* and the internal characters also suggest those shown by KAYSER (1883) and MUIR-WOOD and COOPER (1960). Such being the case the writers prefer to treat the Khao Hin Kling specimens as *Haydenella* until the type species of *Haydenella* will be carefully reexamined by specimens of the topotype materials from Loping, south China.

Haydenella granti, n. sp.

Pl. 29, Fig. 1; Pl. 30, Figs. 2–8

1932. *Linoproductus kiangsiensis*, HUANG. p. 46, pl. 3, figs. 13–15, 19.

Material and Locality: The available specimens are rather rich in number but they are all under a poor state of preservation in the muddy limestone. The holotype, KMNH IvP 610,056, is the exfoliated pedicle valve (Locality O).

Description: Shell small to medium for genus; transversely subrounded; moderately concavo-convex in profile; hinge nearly same with or slightly shorter than largest width; ginglymus present along hinge; cardinal extremities variable in angles, rounded to slightly alate; visceral cavity thin.

Pedicle valve strongly and uniformly convex with largest convexity at umbonal region; flanks not steep and trail short; sulcus not observed in general but very rarely (1 pedicle valve) broad obsolete depression recognizable; ears distinct from flanks. Surface of pedicle valve ornamented by rounded costellae, originating at slightly anterior to umbo as faint striae, rapidly increase in width anteriorly, bifurcation and intercalation very common, neighbouring costellae often unite with each other on anterior half of valve, forming a broad costae with very shallow intercostal furrows and smooth appearance of anterior surface; about 4 or 5 costellae in distance of 5

mm at about midlength; rugae very strong on ears, about 4 or 5 on each ear, disposed nearly at right angle to hinge line, continuing to flanks but suddenly decrease strength; about 3 or 4 spines in row often observed along boundary between ears and flanks; small erect spines sporadically scattered on surface; minute and very tightly arranged growth lines cover whole surface or slightly inner surface of pedicle valve. Because slightly exfoliated valves well show this character. Internal structures of pedicle valve unknown.

Brachial valve moderately concave posteriorly, no geniculation observed; ornament similar to opposite valve; radial costellae obsolete on visceral disc; very fine, tightly arranged concentric lines remarkable on surface of valve, much more remarkable than those of pedicle valve. Brachial valve interior with median septum, anteriorly extending to margin of visceral disc, posteriorly connecting with small sessile cardinal process; detailed character of cardinal process not examined; very fine endospines numerous anteriorly.

Dimensions of 6 specimens as follows (in mm):

	length (ped.v.)	length (br.v.)	length of hinge line	width	thickness
KMNH IvP					
610,053	17.3		14.7	ca. 18.0	ca. 11
610,054		ca. 14	18.5	ca. 20.5	ca. 4
(paratype)					
610,055		17.5	22.2	ca. 29.0	8.5
(paratype)					
610,056	14.3		ca. 13	18.8	9.8
(holotype)					
610,057		13.0	19.5	19.5	ca. 5
610,058	9.0		ca. 17	ca. 18	ca. 5

Remarks: The Khao Hin Kling specimens are characterized by the coarsely costate ornaments and numerous fine growth lines. Except for these characters other characters are well in harmony with those of *Haydenella*. HUANG (1932) described *Haydenella kiangsiensis* (KAYSER) under the name of *Linoproductus* from the Upper Permian *Lyttonia* bed in Guizhou, south China. His figured specimens are all clearly costate shells and the outline, size and other external characters are same with those of the Khao Hin Kling shells. Huang also noticed existence of numerous fine concentric growth lines on the internal surface of brachial valve. This character is revealed more clearly in the Khao Hin Kling specimens. Summarizing these Chinese and Thailand specimens they belong to one and the same species without doubt. This new species might be separated from *Haydenella* because of its strong costae and tightly arranged conspicuous growth lines. YANAGIDA (1964) described *Haydenella kiangsiensis* from a dark mudstone in the Ban Phot area, probably very close

to the present locality. The Ban Phot specimens are all characterized by having the weakly capillate shells with lustrous outer shell layer, and then they are apparently distinguished from the present *Haydenella granti*. The latter species is also different from *Haydenella buravasi* GRANT from the Middle Permian of the Khao Chang area, southern Thailand (GRANT, 1976) by its costate valve.

The new species is named after the late Dr. Richard E. GRANT of Smithsonian Institution, Washington, D.C., who made a great contribution to the development of brachiopod paleontology in Thailand.

Family Marginiferidae STEHLI, 1954

Genus *Marginifera* WAAGEN, 1884

Type-species: *Marginifera typica* WAAGEN, 1884

Marginifera drastica GRANT, 1976

Pl. 29, figs. 2, 3, 5–9

1976. *Marginifera drastica* GRANT. p. 110, pl. 26, figs. 1–23.

Material and Locality: Three silicified specimens from Loc. H and many fragmentary specimens, deformed and mostly composed of moulds, from Loc. T are available. The silicified ones from Loc. H are also incompletely preserved but are without any deformation (Locality H and T).

Description: Shell small to medium for genus; transversely subrounded with strong geniculation in profile; visceral disc slightly rugose; hinge line nearly same with or slightly shorter than widest part; normally widest part at midlength.

Pedicle valve strongly convex with largest convexity at umbonal region; beak slightly incurved over hinge; broad sulcus appears on anterior surface of visceral disc, rather obsolete in general; flanks steep; venter flattened with long trail; ears small; surface ornamented by rounded costae, often remarkable on trail, decreasing in strength posteriorly and rudimentarily marked on visceral disc, about 5 in 5 mm on anterior half; surface covered by numerous erected spines of 2 groups, closely arranged spines in rows on lower part of each flank, close to hinge, about 5 to 8 small erected spines and other erected spines sporadically scattered on visceral disc, venter and trail; visceral disc only rugose. Brachial valve transversely subrounded and concave but trail not observed; surface slightly rugose postero-laterally, anteriorly costate and whole surface pitted.

In pedicle valve only part of lateral ridge observed in auricular region. Brachial valve interior with sessile trilobate cardinal process; lateral ridges curved around visceral disc as raised rim; adductor muscle platforms bending medianly and thin and low median septum under platforms, posteriorly median septum uniting with platforms and continuous to cardinal process as short shaft.

Dimensions of 4 specimens as follows (in mm):

	length (ped.v.)	length (br.v.)	width	thickness
KMNH IvP				
610,059	10 +	8 +	ca. 12	ca. 8
610,060	11.3	9.5	13.0	7.5
610,061		7.5	17.1	4 +
610,062	14.0		ca. 13	4 +

Remarks: *Marginifera drastica* was first described by GRANT (1976) based on the abundant silicified Permian specimens from Phangnga, southern Thailand. According to GRANT the specific characters of *Marginifera drastica* are shown as follows; strong geniculation, costation, weak rugation, numerous lateral spines and relatively few ventral spines. These specific characters of *M. drastica* are quite well in harmony with those of the Khao Hin Kling species. GRANT indicated the conspecific possibility of margiferide specimens from Khao Phrik, southern Thailand, described by WATERHOUSE and PIYASIN (1970) under the name of ? *Marginifera* aff. *elongata* HUANG. The Khao Phrik specimens are rather fragmentary but are characterized by strongly costate valves.

YANAGIDA (1964) described *Marginifera banphotensis* from the same area of Khao Hin Kling. This species is distinguished from *M. drastica* by having largely spinose character of pedicle valve.

Family Dictyoclostidae STEHLI, 1954

Genus *Tyloplecta* MUIR-WOOD and COOPER, 1960

Type-species: *Productus scabriculus* mut. *nankingensis* FRECH, 1911

Tyloplecta cf. *nankingensis* (FRECH), 1911

Pl. 30, fig. 9

cf.

- 1911. *Productus scabriculus* MARTIN mut. *nankingensis* FRECH. p. 163, pl. 22, figs. 3a–c.
- 1927. *Productus nankingensis*, CHAO. p. 54, pl. 8, figs. 12–13.
- 1932. *Productus (Dictyoclostus) nankingensis*, HUANG. p. 28, pl. 2, figs. 1, 2.
- 1960. *Tyloplecta nankingensis*, MUIR-WOOD and COOPER. p. 291, pl. 101, figs. 4–6, pl. 102, figs. 1–13.
- 1964. *Tyloplecta nankingensis*, YANAGIDA. p. 6, pl. 1, fig. 2.
- 1974. *Tyloplecta nankingensis*, JIN, LIAO and FANG. p. 310, pl. 163, figs. 11–13.
- 1978. *Tyloplecta nankingensis*, TONG. p. 229, pl. 80, fig. 9, pl. 81, fig. 2.
- 1982. *Tyloplecta nankingensis*, LIU, TAN and DING. p. 186, pl. 134, fig. 2.

Material and Locality: A pedicle valve, KMNH IvP 610,066, is available with following dimension (in mm): length, ca. 38; width, 38.8; thickness, 20.2 (Locality L).

Descriptive remarks: Shell small size for genus; outline subquadrate; pedicle valve

strongly and evenly convex; sulcus indistinct; flanks steep; ears distinct; venter and trail convex; beak strongly incurved beyond hinge; hinge line represents widest part of shell. Pedicle valve ornamented by strong costae with irregular width, originating near umbo and extend toward anterior margin; erect spines numerous, on nodes of costae on visceral disc, on sulcus and on lower flanks. Brachial valve with similar costae. Pedicle valve interior with broadly striated, diductor muscle scar partly visible.

YANAGIDA (1964) discriminated *Tyloplecta nankingensis* (FRECH) from a locality, west of Ban Phot, in the present surveyed area. The present specimen may belong to one and the same species with the Ban Phot specimen.

Tyloplecta nankingensis (FRECH) is well known in the Lower and Middle Permian of south China, ranging from the Chihhsian to Maokouan. In the Ban Phot area *T. nankingensis* is associated with *T. yangtzeensis* (CHAO). In south China the latter species is known from the lower Upper Permian Longtan Formation (Wujiapingian) of south China.

***Tyloplecta* sp.**

Pl. 31, fig. 1

Material and Locality: A fragmentary pedicle valve, KMNH IvP 610,067, with the following dimension (in mm) is available: length, ca. 39; thickness, ca. 27 (Locality T.).

Descriptive remarks: Shell medium for genus, elongately subquadrate with steep flank, revealing parallel-sided form; ears broken but widest part of shell suggested to along hinge; pedicle valve with strongly convex visceral disc and long trail; beak region destroyed but strong convexity suggests incurved beak beyond hinge; broad and shallow sulcus developed on trail; surface ornamented by coarse prominent costae, more or less uneven with occasional bifurcation; rugose on visceral disc, forming conspicuous nodes on costae; spine bases only discriminated on nodes of visceral disc. Internal structures unknown.

Although the Khao Hin Kling specimen is fragmentary, it is identifiable as a species of *Tyloplecta*. The present species is characterized by its elongately subquadrate form with steep flanks, making the parallel-sided form of shell, and strong costae with remarkable nodes on the visceral disc. In these points the present species is similar to *Tyloplecta costiferinoides* described by FONG (1978) from the Middle Permian Maokouan in Guizhou province, south China. The Chinese species has well developed ears. Although the Khao Hin Kling species lacks ears, other external characters are well in harmony with those of *T. costiferinoides*.

Superfamily Lyttoniaceae WAAGEN, 1883

Family Lyttoniidae WAAGEN, 1883

Genus *Eolyttonia* FREDERIKS, 1923

Type-species: *Oldhamina (Lyttonia) mira* FREDERIKS, 1916

Eolyttonia sp.

Pl. 31, figs. 2 and 3

Material and Locality: Two incomplete specimens, an internal mould of pedicle valve, KMNH IvP 610,063, and an incomplete posterior part of pedicle valve, KMNH IvP 610,064, with cylindrical form and partly with external mould of interior of pedicle valve are available (Locality O).

Descriptive remarks: Shell medium in size for genus; shell form seems to variable, smaller specimen rather long and slender with strongly convex posterior part, larger one shallowly expanded anteriorly in form; external surface ornamented by concentric strong wrinkles.

Pedicle valve interior with at least 11 lateral septa, posterior 3 of them high and slightly inclined anteriorly, gradually decreasing height anteriorly and composed of solidiseptate and angustilobate forms; interseptal callosities well developed anteriorly; both lateral septa and interseptal callosities marked their posterior and anterior surfaces by conspicuous and tightly disposed fine pits or ridges; median trough narrow with low median ridge, very low and thin posteriorly and anteriorly but distinct in median part.

Dimensions of 2 specimens (in mm):

	length	width	height
KMNH IvP			
610,063	26 +	ca. 29	4 +
610,064	33 +	ca. 28	ca. 20

The diagnostic characters of *Eolyttonia* were carefully examined and discussed by COOPER and GRANT (1974). Although the two specimens from the Khao Hin Kling area are so incomplete, they well reveal characters of *Eolyttonia* in different form. *Eolyttonia* is not popular in Asia but it is very common in the Lower and Middle Permian of Texas, ranging from the Wolfcampian to Guadalupian (COOPER and GRANT, 1974). *Eolyttonia?* sp. was described from the Middle Permian of Ko Muk, southern Thailand (GRANT, 1976). The figured specimen (Pl. 43, fig. 17) is externally similar to the present specimens, especially in character of the lateral septa of the pedicle valve interior.

Superfamily Dielasmatacea SCHUCHERT, 1913
Family Notothyrididae LIKHAREV, 1960
Genus *Notothyris* WAAGEN, 1882

Type-species: *Notothyris subvesicularis* DAVIDSON, 1882

Notothyris sakagami, n. sp.
Pl. 32, Figs. 1–10

Material and Locality: 15 tiny to small conjoined shells are available, holotype, KMNH IvP 610,068 (Locality R).

Description: Shell small size for genus; transversely subovate in outline. Pedicle valve strongly convex with largest convexity at slightly anterior to beak; beak suberect with epithyridid foramen. Brachial valve uniformly but weakly convex; height about 1/3 of opposite valve. Both valves ornamented by subangular costae anteriorly; mode of costation and form of anterior commissure variable, normally 4 strong costae developed on anterior half of pedicle valve, median 2 costae longest, originating at slightly anterior to midlength, bounding lateral sides of conspicuous sulcus, 3 costae on anterior third of brachial valve. A pair of very weak costae at outermost part of both valves rather common, consequently 6 costae on pedicle valve and 5 costae on brachial valve often recognized; anterior commissure of juvenile shells characterized by antiplicate or intraplicate form, while in adult shells it represented by zigzaggy form. Internal structures partly recognizable by partly damaged specimen. Pedicle valve interior without dental plates; brachial valve interior with hinge plate and small perforation at posterior margin.

Dimensions of 10 specimens as follows (in mm):

	length	width	thickness	number of costae (ped.v.) (br.v.)	
KMNH IvP 610,068 (holotype)	11.8	9.5	7.7	6	5
610,069	12.5	10.3	8.8	6	5
610,070	11.8	ca. 10	8.4	6	5
610,071	10 +	10.0	7.5	6	5
610,072	9.0	7.9	5.9	4	3
610,073	9.0	7.0	6.1	4	3
610,074	9.0	7.2	6.2	4	3
610,075	8.8	6.7	6.4	2	3
610,076	8.2	7.3	5.1	4	3
610,077	7.8	6.1	4.8	4	3

Remarks: *Notothyris sakagami*, n. sp., is characterized by having the small subovate biconvex shell with strongly convex pedicle valve and anteriorly strongly costate shell with variable mode of costation. The mode of the anterior commissure is also variable in growth. The juvenile shells are very similar to *Notothyris praelecta* REED by WATERHOUSE and PIYASIN (1970) from Khao Phrik, southern Thailand, especially in the mode of costae. GRANT (1976) established a new species, *Notothyris triplexa*, based on the Khao Phrik specimens of WATERHOUSE and PIYASIN with the specimen (pl. 30, figs. 7–9, 1970) as the holotype. GRANT noticed 3 costae on the brachial valve and 4 on the pedicle valve. WATERHOUSE and PIYASIN, however, stated that among the small Khao Phrik specimens a few brachial valves carry suggestions of an extra pair laterally. It means that existence of 3 costae on brachial valve is not a valid character. The variation of costae in the Khao Hin Kling species is rather common character in the young shells. In adult shells costae become very sharp, increasing in number by having a weak pair laterally. *Notothyris sakagami*, n. sp., is closely related to *N. praelecta* REED and *N. ghundiensis* REED, respectively from the Middle and Upper *Productus* Limestones, and the Middle *Productus* Limestone, the Salt Range, West Pakistan (REED, 1944), in the mode of costae. They are, however, different from *N. sakagami* by having the more or less elongate and slender form of shell.

The new specific name is dedicated to Dr. Sumio SAKAGAMI, Professor Emeritus of Chiba University, who contributed greatly to the development of bryozoan paleontology in Thailand and one of our best collaborators.

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Repository: The type specimens and other registered specimens are all kept in the type specimen room of Kitakyushu Museum and Institute of Natural History, Kitakyushu City, with the registered number by the designation KMNH Iv P.

References

- BUCKMAN, S. S. 1906. Brachiopod nomenclature. *Ann. Mag. Nat. Hist. London*, [7], 18: 321–327.
 BUNOPAS, S. 1981. Paleogeographic history of western Thailand and adjacent parts of Southeast Asia. A plate tectonics interpretation. *Ph. D Thesis, Victoria Univ. of Wellington, New Zealand*, 810 pp., Reprinted 1982, *Geol. Sur. Paper (5), Geol. Sur. Div., Dept. Min. Res., Thailand*.

- CHAO, Y. T. 1927. Productidae of China, part 1: Producti. *Geol. Sur. China, Palaeont. Sinica*, [B], 5(2): 1-244, pls. 1-16.
- CHING, Y. K., S. L. YE, H. K. XU and D. L. SUN. 1979. Brachiopoda. In Nanjing Inst. Geol. Pal., Acad. Sinica and Chinghai Inst. Geoscience (eds.), *Paleontological atlas of northwest China, Chinghai, I*, pp. 60-224, Geol. Publ. Beijing (in Chinese).
- COOPER, G. A. and H. M. MUIR-WOOD. 1951. Brachiopod homonyms. *Washington Acad. Sci. Jour.* 41(6): 195-196.
- COOPER, G. A. and R. E. GRANT. 1969. New Permian brachiopods from West Texas. *Smithsonian Contr. Paleobiol.*, 1: 1-20, pls. 1-5.
- COOPER, G. A. and R. E. GRANT. 1974. Permian brachiopods of West Texas, II. *Smithsonian Contr. Paleobiol.*, 14: 233-793, pls. 24-191.
- COOPER, G. A. and R. E. GRANT. 1976. Permian brachiopods of West Texas, IV. *Smithsonian Contr. Paleobiol.*, 21(part 1-text, 1923-2285, part 2-plates, 503-662).
- COX, E. T. 1858 [1857]. Paleontological report of the coal measures Mollusca. *Geol. Sur. Kentucky*, 3: 555-576, pls. 1, 2.
- DERBY, O. A. 1874. On the Carboniferous Brachiopoda of Itaituba, Rio Tapajos, Prov. of Para, Brazil. *Cornel Univ. Sci. Bull.*, 1(2): 1-63, pls. 1-9.
- FONG, R. L. 1978. Carboniferous to Quaternary Brachiopoda. In Acad. Sin. Geol. SW China (ed.), *Paleontological atlas of southwest China, Guizhou*, 2, pp. 231-304, pls. 85-108, Geol. Publ. Beijing. (in Chinese).
- FRECH, F. 1911. Die Dyas. In RICHTHOFEN, F. von (ed.), *China*, 5, pp. 103-202, pls. 19-28.
- FREDERIKS, G. 1924 (1923). Upper Paleozoic of the Ussuriland, I: Brachiopoda. *Rec. Geol. Com. Russian Far East.*, 28: 1-52.
- GIRTY, G. H. 1904. New mollscan genera from the Carboniferous. *Proc. U. S. Nat. Mus.*, 27(1372): 721-736, pls. 45, 46.
- GRANT, R. E. 1970. Brachiopods from Permian-Triassic boundary beds and age of Chhidru Formation, West Pakistan. In KUMMEL, B. and C. TEICHERT (eds.), *Stratigraphic boundary problems: Permian and Triassic of West Pakistan*, pp. 117-151, pls. 1-3 Univ. Kansas Spec. Pub. 4.
- GRANT, R. E. 1976. Permian brachiopods from southern Thailand. *J. Paleont.*, 50, Supplement (3), Mem. 9: 1-269, pls. 1-71.
- HALL, J. and J. M. CLARKE. 1892. An introduction to the study of the genera of Palaeozoic brachiopoda. *N. Y. Geol. Surv.*, 8, pt. 1, 1-367, pls. 1-20.
- HALL, J. and J. M. CLARKE. 1893. An introduction to the study of the genera of Palaeozoic brachiopoda. *N. Y. Geol. Surv.*, 8, pt. 2, 1-317.
- HUANG, T. K. 1932. Late Permian brachiopods of southwest China. *Geol. Surv. China, Palaeont. Sinica*, [B], 9(1): 1-138, pls. 1-9.
- JIN, Y. G., Z. T. LIAO and B. X. FANG. 1974. Permian brachiopoda. In Nanjing Inst. Geol. Paleont., Acad. Sin. (ed.), *Geological and paleontological handbook of southwest province*, pp. 308-313, pls. 162-165, Sci. Publ., Beijing (in Chinese).
- KAYSER, E. 1883. Obercarbonische Fauna von Loping. In RICHTHOFEN, F. von (ed.), *China*, 4, pp. 160-208, pl. 21.
- LIANG, W. P. 1990. Lengwan Formation of Permian and its brachiopod fauna in Zhejiang province. *Geol. Mem. Geol. Inst. Zhejiang*, [2], 10: 1-522, pls. 1-84 (in Chinese with English abstract).
- LIAO, Z. T. 1980. Upper Permian brachiopods from western Guizhou. In Nanjing Inst. Geol. Paleont. Acad. Sin. (ed.), *Palaeontology and stratigraphy of late Permian Coal Measures in eastern Yunnan-western Guizhou*, pp. 241-277, pls. 1-9, Science Press. (in Chinese).
- LIU, Z. H., Z. X. TAN and Y. L. DING. 1982. Brachiopoda. In Geol. Bureau of Hunan (ed.), *The*

- palaeontological atlas of Hunan*, pp. 172–216, pls. 125–159, Geol. Publ., Beijing (in Chinese).
- MUIR-WOOD, H. M. and G. A. COOPER. 1960. Morphology, classification and life habits of the Productoidea (Brachiopoda). *Geol. Soc. Amer. Mem.* 81: xi + 1–447, pls. 1–135.
- NAKORSRI, N. 1976. *Geological map of Amphoe Ban Mi. Sheet ND 77–4, ser. 1: 250,000*. Geol. Surv. Div., Dept. Min. Resources, Thailand.
- NAKORSRI, N. 1981. Geology and Mineral Resources of Amphoe Ban Mi ND 47–4). *Geol. Surv. Rep., Dept. Min. Resources, Thailand*, (3): 1–36.
- PAVLOVA, E. E. 1965. Revizhia Roda *Neophricodothyris* (Otryad Spiriferida). *Paleont. Zhurnal*, (2): 133–137 (in Russian). English translation in *Intern. Geol. Review* 8(1): 84–88.
- REED, F. R. C. 1944. Brachiopoda and Mollusca from the *Productus* Limestones of the Salt Range. *Geol. Sur. India Mem., Palaeont. Indica*, n. s., 23(2): xiv + 1–678, pls. 1–65.
- RUZHENTSEV, V. E. and T. G. SARYCHEVA. 1965. The development and change of marine organisms at the Paleozoic-Mesozoic boundary. *Akad. Nauk. SSSR, Paleont. Inst. Trudy*, 108: 1–431, pls. 1–58 (in Russian).
- SHELLWIEN, E. 1900. Die Fauna der Trogkofelschichten in den Karnischen Alpen und der Karawanken, I: Die Brachiopoden. *Abhandl. des Kaiserlich-Koeniglichen Geol. Reichsanst., Wien*, 16(1): 1–122, pls. 1–15.
- SESTINI, N. F. and M. GLAUS. 1966. Brachiopods from the Upper Permian Nesen Formation (North Iran). *Riv. Ital. Paleont.*, 72(4): 887–930, pls. 63–66.
- TONG, Z. X. 1978. Permian and Carboniferous Brachiopoda. In Acad. Sin. Geol. SW China (ed.), *Paleontological atlas of Southwest China, Sichuan*, 2, pp. 210–267, pls. 77–92, Geol. Publ., Beijing (in Chinese).
- WAAGEN, W. H. 1882. Salt Range fossils, pt. 4: (2) Brachiopoda. *Geol. Sur. India Mem., Paleont. Indica*, [13], 1(1): 329–390, pls. 25–28.
- WAAGEN, W. H. 1884. Salt Range Fossils, pt. 4: (2) Brachiopoda. *Geol. Sur. India Mem., Paleont. Indica*, [13], 1(3): 547–610, pls. 50–57.
- WANG, Y. 1955. New Genera of brachiopods. *Scientia Sinica*, 4(2): 327–357, pls. 1–6.
- WANG, Y. 1956. New species of brachiopods, II. *Acta Paleont. Sinica*, 4(3): 385–405 (in Chinese).
- WARDLAW, B. R. and K. R. POGUE. 1995. The Permian of Pakistan. In SCHOLLE, P. A., T. M. PERYT and D. S. ULMER-SCHOLLE (eds.), *The Permian of Northern Pangea, 2: Sedimentary Basins and Economic Resources*, pp. 215–224, Springer-Verlag Publ.
- WATERHOUSE, J. B. 1983. A late Permian lytoniid fauna from northwest Thailand. *Pap. Dep. Geol. Univ. Qld.*, 10(3): 111–153, pls. 1–6.
- WATERHOUSE, J. B. and S. PIYASIN. 1970. Mid-Permian brachiopods from Khao Phrik, Thailand. *Palaeontographica*, [135], A, 83–197, pls. 14–32.
- YANAGIDA, J. 1964. Permian brachiopods from central Thailand. *Mem. Fac. Sci., Kyushu Univ.*, 15(1): 1–22, pls. 1–3.
- YANAGIDA, J. 1970. Permian brachiopods from Khao Phrik, near Rat Buri, Thailand. *Contr. Geol. Palaeont. SE Asia*, LXXXI. In KOBAYASHI, T. (ed.), *Geology and Palaeontology of Southeast Asia*, 8, pp. 69–96, pls. 14–16.
- YANAGIDA, J. 1988. Biostratigraphic study of Paleozoic and Mesozoic Groups in central and northern Thailand. In YANAGIDA, J. (ed.), *An Interim Report by the Research Group*, pp. 1–47, pls. 1–33.
- YANG, Z. Y., L. P. ZHAN, J. D. YANG and S. B. WU. 1997. Permian chronostratigraphic subdivisions and events in China. In J. M. DICKINS (ed.), *Late Paleozoic and Early Mesozoic circum Pacific events and other global correlation*, pp. 66–86, Cambridge Univ. Press.

Permian Brachiopods from the Khao Hin Kling Area near
Phetchabun, North-central Thailand

Juichi YANAGIDA and Nikorn NAKORNSRI

Plates 26–32

Explanation of Plate 26

Figs. 1–7. *Acosarina kanmerai*, n. sp.

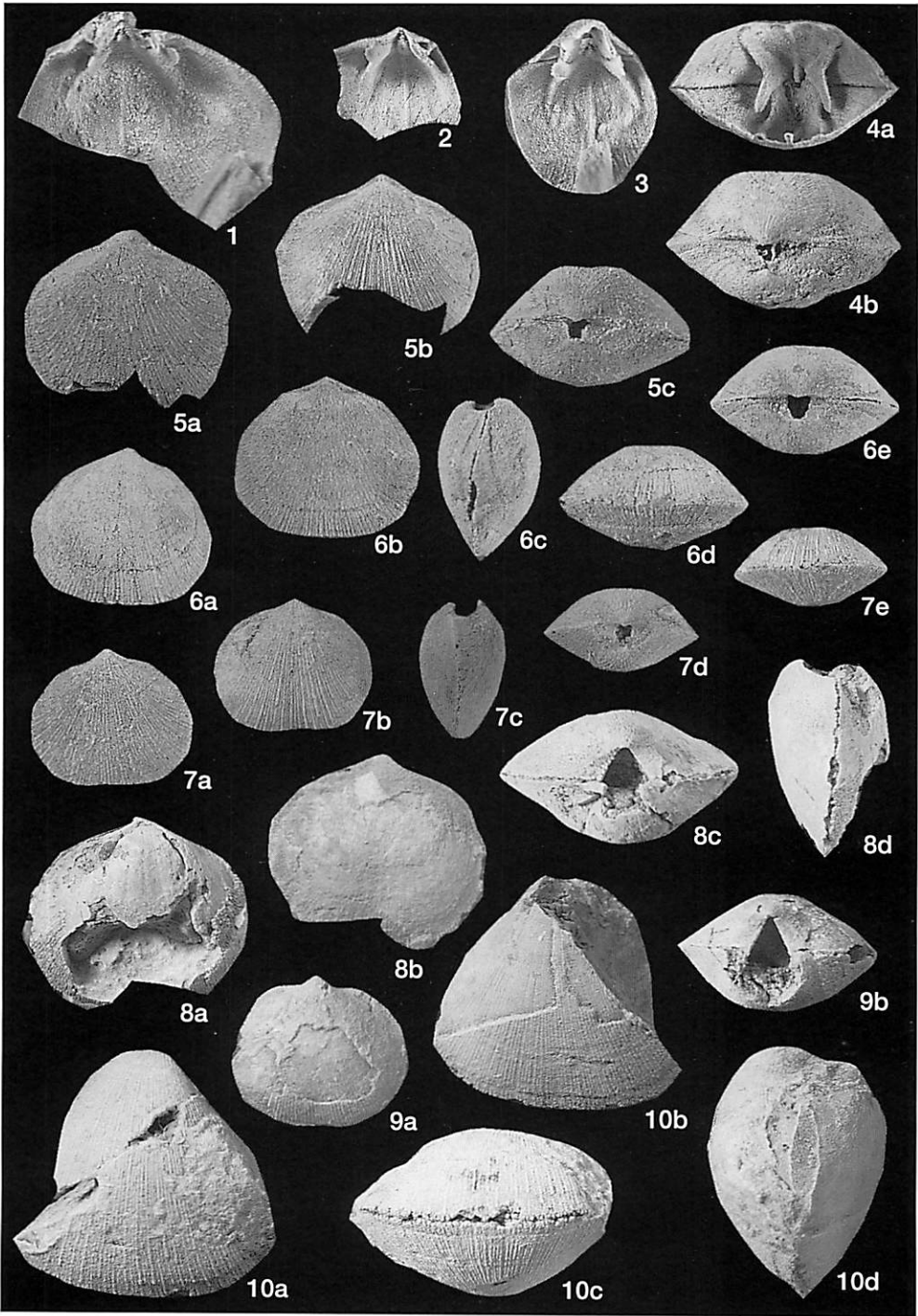
1 and 2, Posterior part of brachial valve interiors, $\times 2$, respectively KMNH Iv P 610080 and 610081, showing small cardinal process, sockets and brachiophore supports; 3, conjoined valves with a part of pedicle valve only preserved in the posterior region, KMNH IvP 610,082, $\times 2$; 4a and b, respectively internal and external views of a posteriorly preserved conjoined valves, KMNH IvP 610,083, showing articulation, $\times 2$; 5a–c, pedicle, brachial and posterior views of an incomplete specimen, KMNH IvP 610,007, $\times 2$; 6a–c, brachial, pedicle, lateral, anterior and posterior views of the holotype, KMNH IvP 610,001, $\times 2$; 7a–c, pedicle brachial, lateral, posterior and anterior views of a younger complete specimen, KMNH IvP 610,005, $\times 2$.

Figs. 8 and 9. *Orthotichia* sp. A

8a–d, brachial, pedicle, posterior and lateral views of an incomplete specimen, KMNH IvP 610,011, $\times 2$; 9a and b, pedicle and posterior views of a small specimen, KMNH IvP 610,012, $\times 2$.

Fig. 10. *Orthotichia* sp. B

10a–d, brachial, pedicle, anterior and lateral views of a fragmentary specimen, KMNH IvP 610,014, $\times 2$.



Explanation of plate 27

Figs. 1–8. *Schuchertella* cf. *cooperi* GRANT

1a, b, brachial and antero-brachial views of a pedicle valve, KMNH IvP 610,015, $\times 2$; 2 and 4, fragmentary brachial valve interiors, showing cardinal process, respectively KMNH IvP 610,094, $\times 2$ and 610,095, $\times 3$; 3, 6–8, brachial views of fragmentary pedicle valves showing pseudodeltidium, interarea and pointed teeth, respectively KMNH IvP 610,096, 610,097, 610,098 and 610,017, $\times 2$; 5, brachial valve exterior of a specimen, KMNH IvP 610,016, $\times 2$.

Figs. 9 and 11, *Orthotetina* *ruchae*, n. sp.

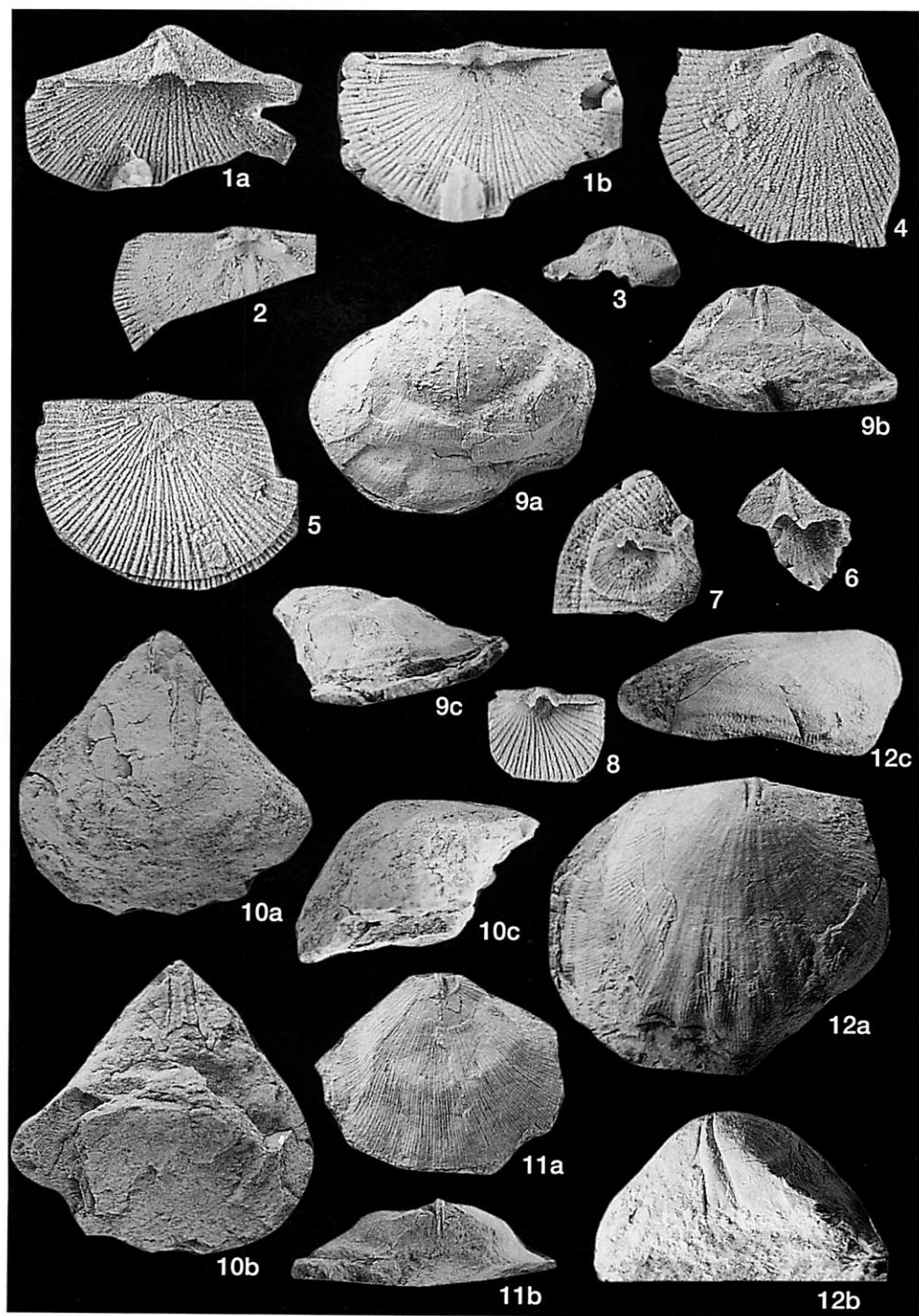
9a–c, pedicle, posterior and lateral views of the holotype, KMNH IvP 610,023, showing broad wrinkle of growth on the surface of pedicle valve, high and narrow interarea, narrow hinge and narrowly parallel dental plates, $\times 1$; 11a and b, pedicle and posterior views of a specimen, KMNH IvP 610,021, $\times 1.5$.

Fig. 10. *Orthotetina* sp.

10a–c, pedicle, brachial and lateral views of an incomplete pedicle valve, KMNH IvP 610,025, showing highly projected interarea and short hinge line, $\times 1.5$.

Fig. 12. *Meekella* aff. *arakeljani* (SOKOLSKAJA)

12a–c, pedicle, postero-brachial and lateral views of a slightly exfoliated pedicle valve, KMNH IvP 610,020, $\times 1.5$.



Explanation of Plate 28

Fig. 1. *Callispirina* aff. *austrina* GRANT

1a–c, pedicle, lateral and brachial views of a half damaged specimen, KMNH IvP 610,032, × 3.

Figs. 2–6. *Cleiothyridina* sp.

Slightly exfoliated pedicle valves, respectively KMNH IvP 610,034, 610,033, 610,036, 610,037 and 610,035, showing remarkable pallial markings, longitudinally disposed in parallel and an anterior shallow depression on pedicle valve, × 2.

Figs. 7–9. *Permophricodothyris*? sp. A

7 and 9, incomplete pedicle valves, respectively KMNH IvP 610,039 and 610,042, × 2; 8, a brachial valve, KMNH IvP 610,041, showing fine spine bases, × 2.

Figs. 10–12. *Permophricodothyris*? sp. B

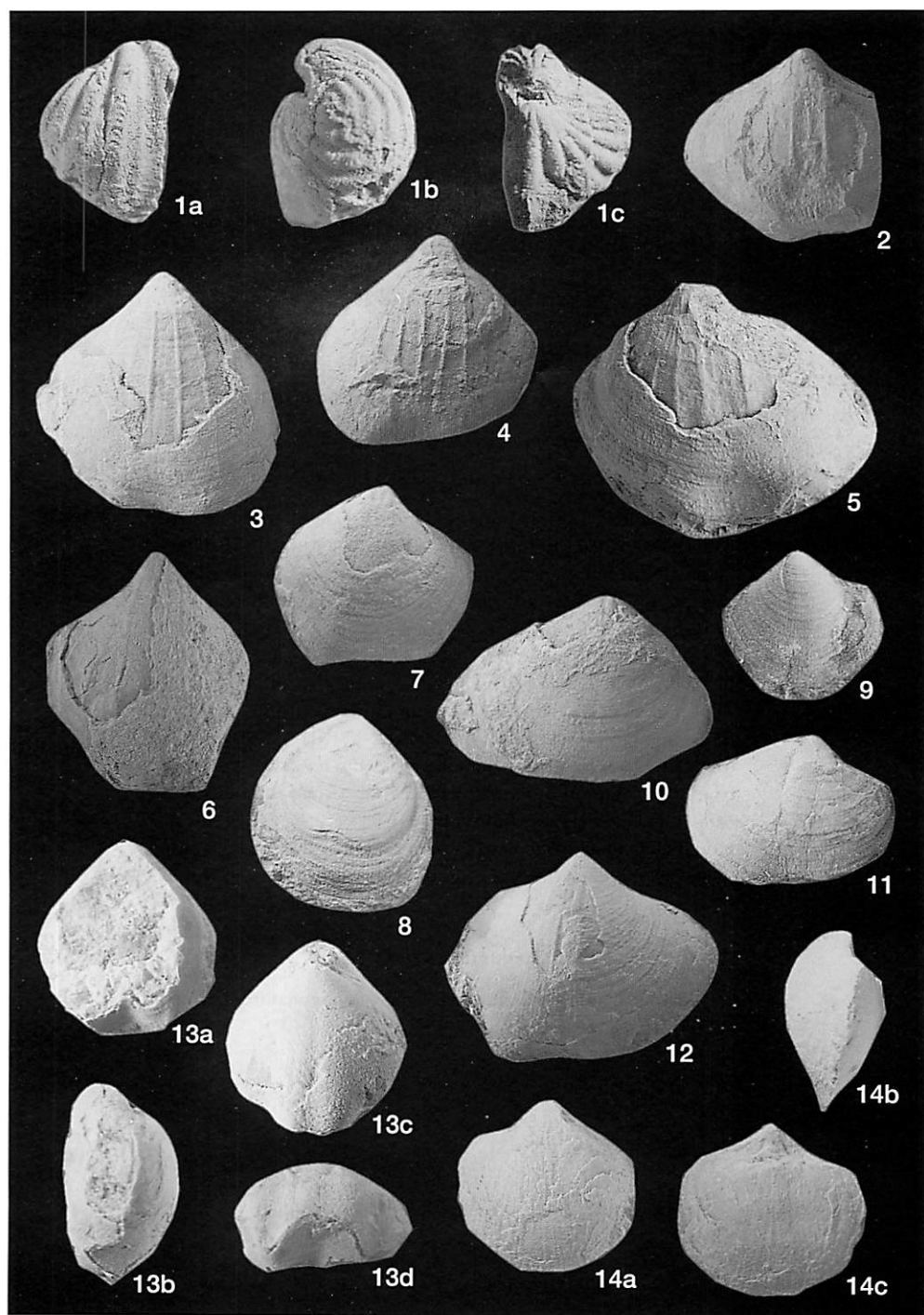
Incomplete pedicle valves, respectively KMNH IvP 610,100, 610,099 and 610,048, × 2.

Fig. 13. *Araxathyris* cf. *araxensis* GRUNT

13a–d, pedicle, lateral, brachial and anterior views of a partly damaged specimen, KMNH IvP 610,054, showing a shallow sulcus on the fold of brachial valve and sulcificate anterior commissure, × 2.

Fig. 14. *Orbicoelia* aff. *extima* (GRANT)

14a–c, pedicle, lateral and brachial views of a small conjoined specimen, KMNH IvP 610,052, showing a wide hinge and the less convex brachial valve than the opposite valve, × 3.



Explanation of Plate 29

Fig. 1. *Haydenella granti*, n. sp.

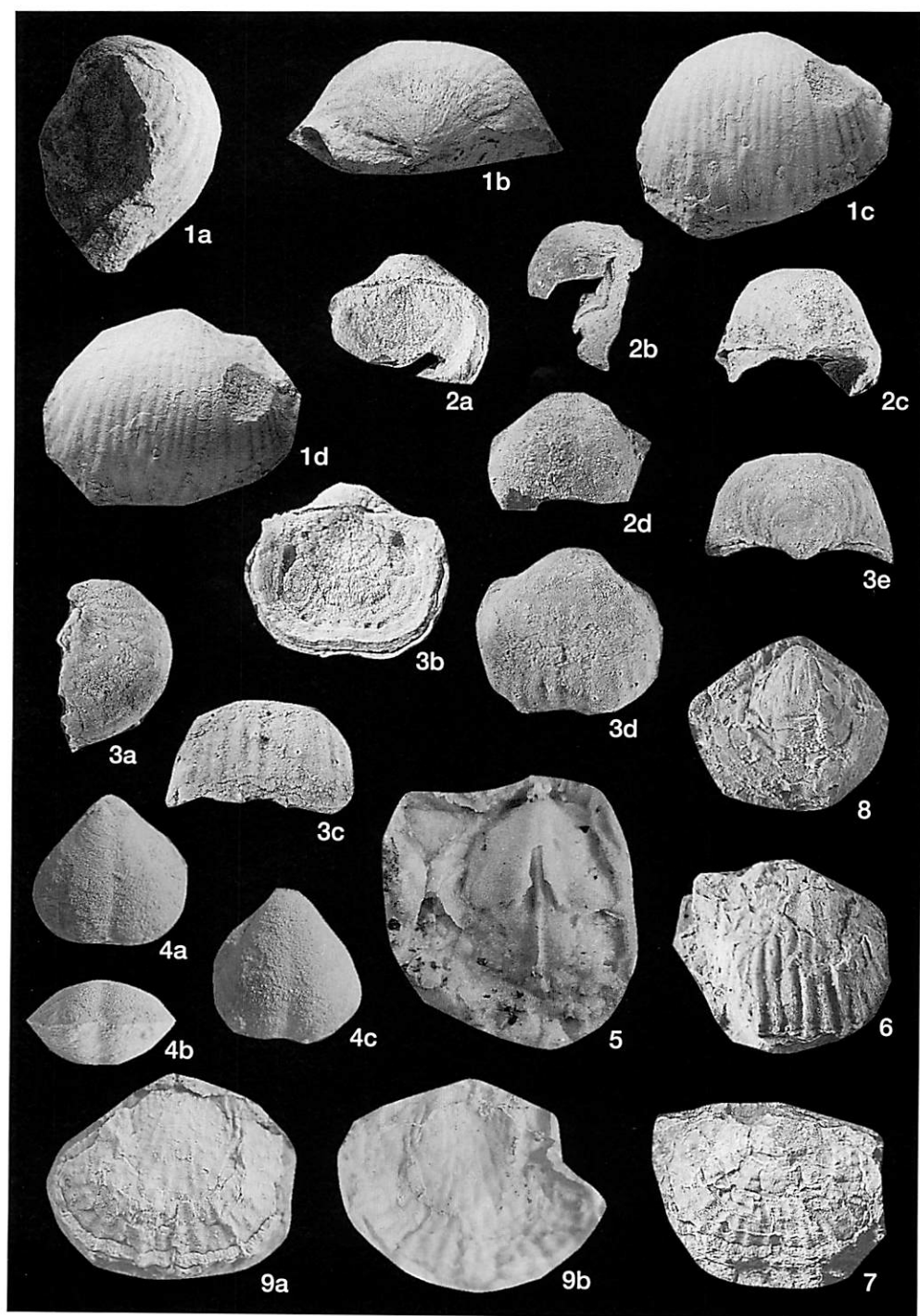
1a–d, lateral, posterior, anterior and pedicle views of the holotype, KMNH IvP 610,056, $\times 1.5$.

Figs. 2–3, 5–9. *Marginifera drastica* GRANT

2a–d, brachial, lateral, posterior and pedicle views of a partly damaged silicified specimen, KMNH IvP 610,059, $\times 2$; 3a–e, lateral, brachial, anterior, pedicle and posterior views of a young conjoined specimen, KMNH IvP 610,060, $\times 2$, showing mode of the surface ornamentation and the anterior arrangement of the marginal rim; 5, a rubber replica of an internal surface of brachial valve, KMNH IvP 610,086, showing sessile trilobate cardinal process, low median ridge and medially conjoined adductor muscle platforms, $\times 3$; 6 and 8, incomplete pedicle valves, respectively KMNH IvP 610,084 and 610093, showing a row of spine bases on the lower flank, and the rounded costae on anterior surface; 7, an external mould of an exfoliated brachial valve, KMNH IvP 610,085, $\times 2$; 9a and b, external mould of an incomplete brachial valve and the rubber cast, showing the raised marginal rim and small trilobate cardinal process, respectively, $\times 2$.

Fig. 4. *Araxathyris* cf. *araxensis* GRUNT

4a–c, brachial, anterior and pedicle views of an immature specimen, KMNH IvP 610,053, $\times 3$.



Explanation of Plate 30

Fig. 1. *Linoproductus* sp.

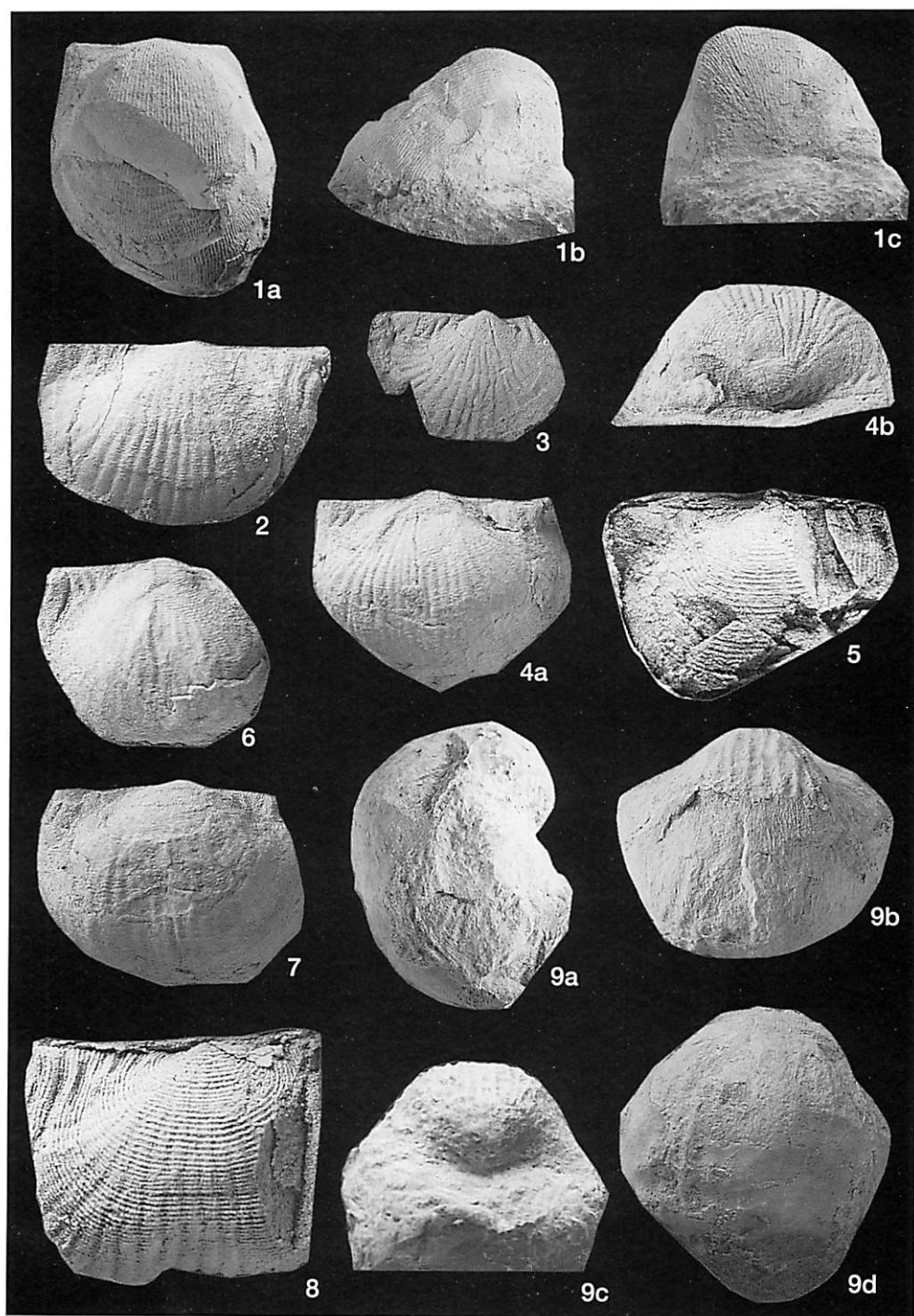
1a–c, pedicle, lateral, and posterior views of a partly damaged conjoined specimen, KMNH IvP 610,065, $\times 1$.

Figs. 2–8. *Haydenella granti*, n. sp.

2, external mould of a brachial valve, KMNH IvP 610,078 $\times 2$; 3, external mould of a small brachial valve, KMNH IvP 610,082, $\times 3$; 4a and b, pedicle and posterior views of a slightly exfoliated pedicle valve, a paratype, KMNH IvP 610,055, $\times 1.5$; 5, external mould of a brachial valve, 610,081, $\times 2.5$; 6, a slightly exfoliated pedicle valve, KMNH IvP 610,058, $\times 1.5$; 7, an exfoliated pedicle valve, KMNH IvP 610,079, $\times 2$; 8, external mould of an incomplete and exfoliated brachial valve, KMNH IvP 610,080, $\times 3$.

Fig. 9. *Tyloplecta* cf. *nankingensis* (FRECH)

9a–d, lateral, posterior, brachial and pedicle views of an incomplete pedicle valve, KMNH IvP 610,066, $\times 1$, showing mode of costation and arrangement of nodes on costae in posterior region.



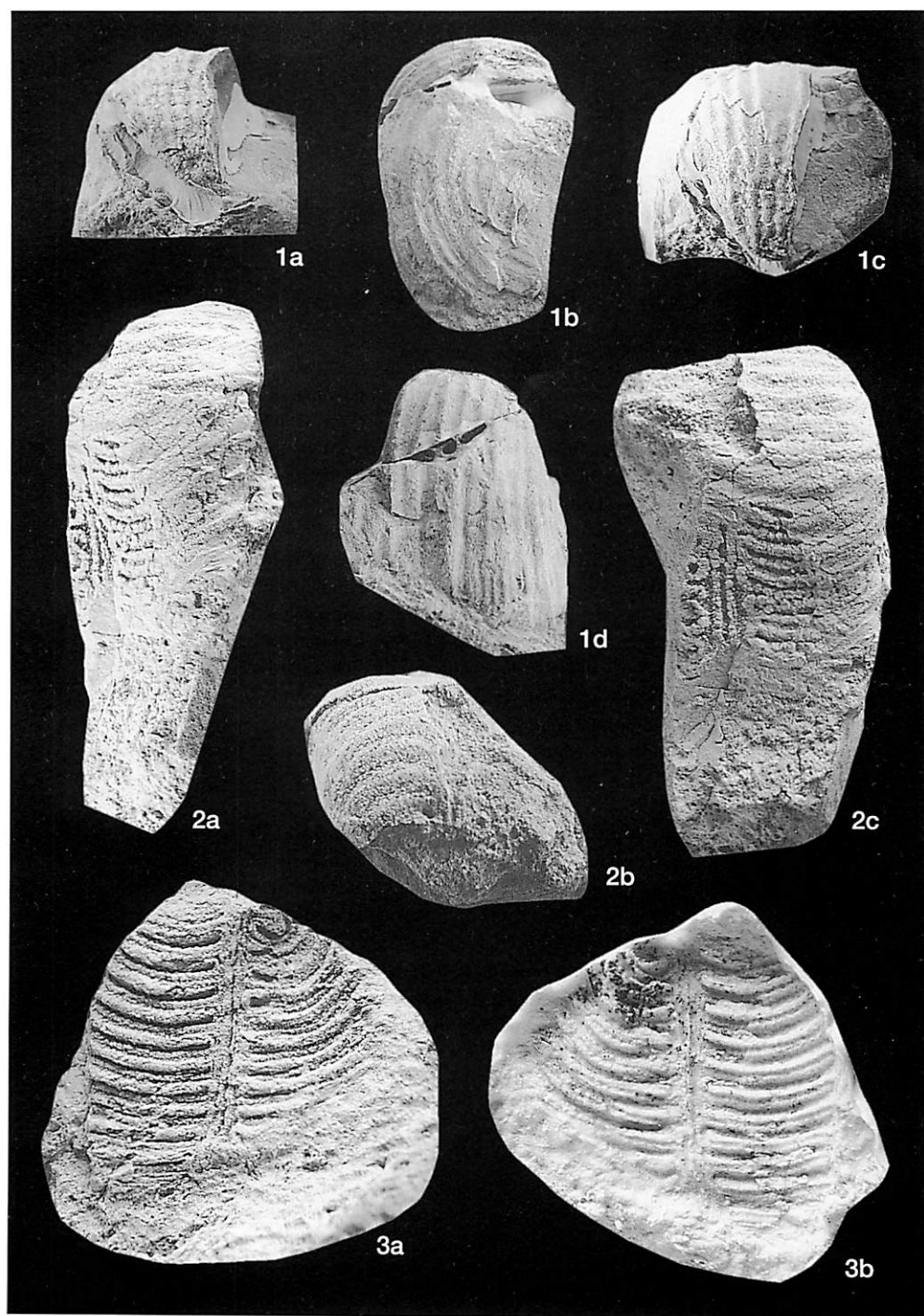
Explanation of Plate 31

Fig. 1. *Tyloplecta* sp.

1a–d, brachial, lateral, posterior and pedicle views of a fragmentary pedicle valve, KMNH IvP 610,067, $\times 1$.

Figs. 2 and 3. *Eolyttonia* sp.

2a–c, lateral, posterior and pedicle views of a cylindrically elongated pedicle valve, KMNH IvP 610,064, $\times 1.5$; 3a and b, an internal mould of pedicle valve and the rubber replica, respectively, KMNH IvP 610,063, $\times 1.5$, showing solidiseptate and angustilobate forms of the lateral septa and fine pits on the lateral septa and interseptal callosities.



Explanation of Plate 32

Figs. 1–10. *Notothyris sakagami*, n. sp.

1a–d, anterior, pedicle, lateral and brachial views of a partly damaged specimens, KMNH IvP 610,069, $\times 2$; 2a–d, pedicle, lateral, anterior and brachial views of the holotype, KMNH IvP 610,068, $\times 2$; 3a–d, pedicle, brachial, lateral and anterior views of a posteriorly damaged specimen, KMNH IvP 610,071, $\times 2$, showing anteriorly remarkable costae; 4a–c, brachial, anterior and lateral views of an adult specimen, KMNH IvP 610,089, $\times 2$; 5a–c, pedicle, brachial and anterior views of a young specimen, KMNH IvP 610,072, $\times 2$; 6a–c, brachial, lateral and anterior views of a young specimen, KMNH IvP 610,073, $\times 2$; 7a and b, pedicle and lateral views of a young specimen, KMNH IvP 610,077, $\times 2$; 8a–c, anterior, pedicle and brachial views of a young specimen, KMNH IvP 610,075, $\times 2$; 9a and b, lateral and brachial views of a young specimen, KMNH IvP 610,088, $\times 2$; 10a and b, anterior and brachial views of a young specimen, KMNH IvP 610,076, $\times 2$.

Figs. 11–16. *Hustedia ratburiensis* WATERHOUSE and PIYASIN

11a and b, pedicle and brachial views of a young specimen, KMNH IvP 610,028, $\times 2$; 12a and b, brachial and pedicle views of a specimen, KMNH IvP 610,027, $\times 2$; 13a and b, brachial and pedicle views of a specimen, KMNH IvP 610,030, $\times 2$; 14a and b, brachial and pedicle views of a young specimen, KMNH IvP 610,031, $\times 2$; 15a and b, pedicle and brachial views of a specimen, KMNH IvP 610,029, $\times 2$; 16a and b, brachial and pedicle views of a rubber replica of an adult specimen, KMNH IvP 610,026, $\times 2$.

